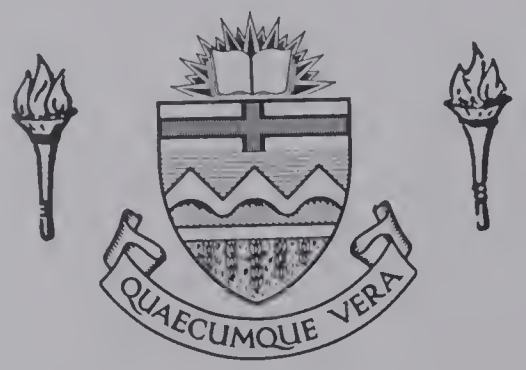

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THE UNIVERSITY OF ALBERTA

AN INVESTIGATION OF RETENTION IN PHYSICS BY GRADE XI STUDENTS DETERMINED ON THE BASIS OF THE CATEGORIES OF BLOOM'S TAXONOMY OF EDUCATIONAL OBJECTIVES

by

Floyd Walter McMillan

A THESIS

SUBMITTED TO THE FACULTY OF GRADUATE STUDIES

IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE DEGREE

OF MASTER OF EDUCATION

DEPARTMENT OF SECONDARY EDUCATION

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FACULTY OF GRADUATE STUDIES

The undersigned certify that they have read, and recommend to the Faculty of Graduate Studies for acceptance, a thesis entitled "An Investigation of Retention in Physics by Grade XI Students, Determined on the Basis of the Categories of Bloom's Taxonomy of Educational Objectives" submitted by Floyd Walter McMillan in partial fulfilment of the requirements for the degree of Master of Education.

ABSTRACT

This study represents an attempt to determine, when subject-matter in Science 20 Physics is classified in various categories of Bloom's Taxonomy of Educational Objectives, Cognitive Domain, whether retention is significantly different in some categories than in others.

Subjects of the investigation were one-hundred-and-seventy Grade XI students in fifteen schools of north-eastern Alberta.

The instrument used was a test designed by the writer, with items classified in categories of Bloom's Taxonomy as follows:

1.1 Knowledge of specifics

1.2 Knowledge of ways and means of dealing with specifics

1.3 Knowledge of universals and abstractions in a field

2 Comprehension

3 Application

4 Analysis

5 Synthesis

6 Evaluation

The test was administered in June and again in September. Test and retest performances were compared for

(a) the student group as a whole, using t-tests,

(b) upper, middle, and lower third of sample, using analysis of variance, with grouping on basis of

(i) June test,

(ii) September retest,

(iii) Grade IX ability percentile rating,

(c) two groups on the basis of sex.

The investigation revealed significant differences between test and retest means for the entire group in categories 1.1, 1.2, 1.3, and 3, and on the test as a whole. No significant differences appeared between means in categories 2, 4, 5, and 6. That is, there was significant forgetting in the categories of knowledge and its applications, but no appreciable loss in ability to comprehend, analyze, synthesize, and evaluate.

There were significant differences between groups in their retention in some categories, but these differences varied depending on the basis of formation of groups.

Boys surpassed girls in their retention of "ways and means of dealing with specifics," and in total amount retained. This may be due to the generally greater interest of boys in the subject of physics, and more contact with its practical applications.

In general it can be said that retention of more structured learnings as represented by the higher categories of Bloom's Taxonomy proved to be better than that of the simpler, less related types.

ACKNOWLEDGEMENTS

The writer wishes to express his appreciation for the assistance received during this study. The help and encouragement given by Dr. M. A. Nay, chairman, along with that of the committee members, Dr. Harvey Zingle, Dr. John Ivany, and his successor on the committee, Dr. D.W.R. Wilson, are gratefully acknowledged.

The writer also expresses his gratitude to the superintendents of the school divisions and counties and the principals and teachers who so kindly co-operated in gathering the data which made this study possible.

TABLE OF CONTENTS

CHAPTER PAGE

LIST OF ILLUSTRATIONS

LIST OF TABLES

CHAPTER I

INTRODUCTION TO THE PROBLEM

A proposition which finds general agreement among educators is that an important immediate objective of teaching is to develop the learner's cognitive skills and abilities in the subject-matter of the course. Just what different skills and abilities should be developed, and their relative importance, is not so clearly agreed upon, nor is there general agreement on the function of these in the desired outcomes of education. (1, pp. 5 and 6)

However, it is assumed that, to be functional, cognitive skills and abilities must be retained. This assumption leads further to interesting speculation as to whether some types of skills and abilities are retained better than others. The purpose of the study herein described is to investigate this question and to try to provide an answer.

Some very important milestones have been reached by modern educators in the classification of educational goals. The "Taxonomy of Educational Objectives, Handbook I: Cognitive Domain," by Benjamin S. Bloom, (2) is receiving widespread attention at the present time.

BLOOM'S TAXONOMY

Bloom's Taxonomy offers a very convenient classification by means of which cognitive skills and abilities in a given subject can

be separated into different categories for a study such as the one here described, in which eight categories are used. These are listed and briefly defined as follows:

1.00 Knowledge (Remembering facts, terms and principles in the form that they were learned)

1.1 Knowledge of Specifics

Terminology, specific facts

1.2 Knowledge of Ways and Means of Dealing with Specifics

Conventions, trends and sequences, classifications, and categories, criteria, methodology

1.3 Knowledge of Universals and Abstractions in a Field

Principles and generalizations, theories and structures

2.00 Comprehension (Understanding the material studied without necessarily relating it to other material) Translation, interpretation, extrapolation

3.00 Application (Using generalizations or other abstractions appropriately in concrete situations)

4.00 Analysis

Analysis of elements, of relationships, or of organizational principles

5.00 Synthesis

Production of a unique communication, of a plan or proposed set of operations, or derivation of a set of abstract relations

6.00 Evaluation

(Judging the value of material for a specified purpose) Judgments in terms of internal evidence (for example, logical consistency) and judgments in terms of external criteria

In summary it can be said that the taxonomy is hierarchical in structure, with attainment in each higher order depending on mastery of the classes below it. However, this is not to say that a higher order ability can not be retained after some of the material in the classes below it, which originally contributed to the learning of it, has been forgotten. In this connection it is interesting to note the findings of Gagné and Bassler (3, p. 128) and others discussed in the next chapter.

STATEMENT OF THE PROBLEMS

This study is designed to investigate the following problems, and to try to find answers to the questions posed by these problems.

Problem 1

Part A

When the test items of Science 20 Physics are classified in the eight categories of Bloom's Taxonomy previously described, will there by any significant differences in students' retention between these different categories?

Part B

When classification of test items is in three groups of categories of Bloom's Taxonomy as follows: Group I, Knowledge (including specifics, ways and means of dealing with specifics, and universals and abstractions), Group II, Comprehension and Application, and Group III, Analysis, Synthesis and Evaluation, will there be any significant differences in students' retention between these different groups of categories?

Problem 2

Are there any significant differences between different student groups in their retention of subject-matter in the various categories of Bloom's Taxonomy when the groups are formed as follows:

(a) upper, middle, and lower third of sample, on the basis of

(i) June test in Science 20 Physics?

(ii) September retest in Science 20 Physics?

(iii) Grade IX ability percentile ratings?

(b) two groups on the basis of sex?

DEFINITION OF TERMS

Grade IX Ability Percentile Rating: Percentile rank attained on the "School and College Ability Test" (SCAT) administered as one of the final Departmental examinations to all Grade IX students in Alberta.

SCOPE AND LIMITATIONS OF THE STUDY

This study is limited to the physics section of Science 20.

The chief research tool, a test, which was also used as retest, consisted of fifty items which were all of the multiple choice type.

Test items were categorized on the basis of Bloom's Taxonomy and assigned to their "best fit" category by majority consensus of the writer and his committee of advisers. However, especially between higher categories, differences are subtle, and overlap is inevitable. Therefore, unquestionable accuracy in categorization of test items cannot be claimed.

Students were not pre-tested to determine what knowledge of the subject-matter of Science 20 Physics they possessed before taking the course.

Only those schools in which the principal and his staff co-operated to the extent of returning both test and retest papers are included in the sample. This imposes some limitation on representativeness of the sample.

SIGNIFICANCE OF THE STUDY

Classroom teachers are keenly interested in knowing what lasting effects can be expected from their teaching. A study of the relative retention of different cognitive skills and abilities

will indicate what types of learning should be striven for - whether, for example, facts may be taught in isolation or must be parts of integrated wholes.

What residue remains after factual material is forgotten? That it is largely forgotten in a relatively short time has been convincingly shown by such studies as those of Johnson in botany (4, pp. 37-47), Eurich (5, pp. 209-219) and Watson in psychology (6, No. 225), Greene in physics and chemistry (7, pp. 262-273), Cederstrom in zoology (8, pp. 516-520), and others mentioned in the next chapter.

Yet the ability to apply principles learned and to interpret new situations has been shown to suffer no diminution, and even to increase with time, in such studies as those of Tyler in biology (9, pp. 133-142) and in high school general science (10, pp. 490-492), and in those of Wert (11, pp. 136-140) and others.

CHAPTER II

REVIEW OF RELATED LITERATURE

It is widely believed in educational circles that meaningful material, that is, material which is structured and related to its context, is retained in the mind more effectively than that which is secured by rote. Among early workers to draw attention to this proposition was Ebbinghaus, who found that his memory was much more efficient for stanzas of Byron's "Don Juan" than for lists of nonsense syllables. (12, pp. 50-51 and 82-85) The Ebbinghaus curve of retention for nonsense syllables is shown in Figure 1.

A series of studies done by Davis and Moore compared retention of meaningful with that of meaningless verbal materials as measured by the recall method. (13, pp. 144-155) The results, based on 18 studies with meaningless material and 24 studies with meaningful material, are best illustrated by the two retention curves shown in Figure 2.

Acting as spokesman for a large group of educators, Bruner says,

> Perhaps the most basic thing that can be said about human memory after a couple of centuries of intensive research is that unless detail is placed into a structured pattern, it is rapidly forgotten. (14, p. 24)

The Ebbinghaus Curve of Retention

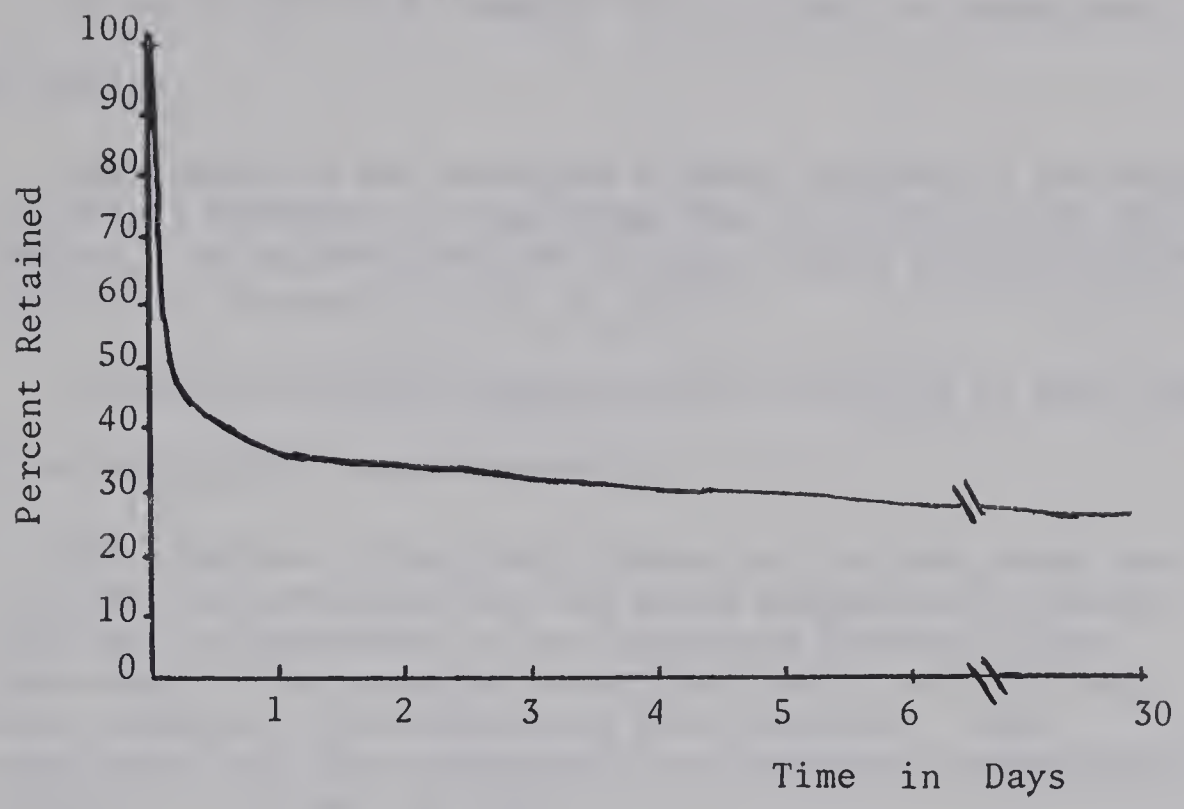


Figure 1

Retention Curves for Meaningful and Meaningless Material

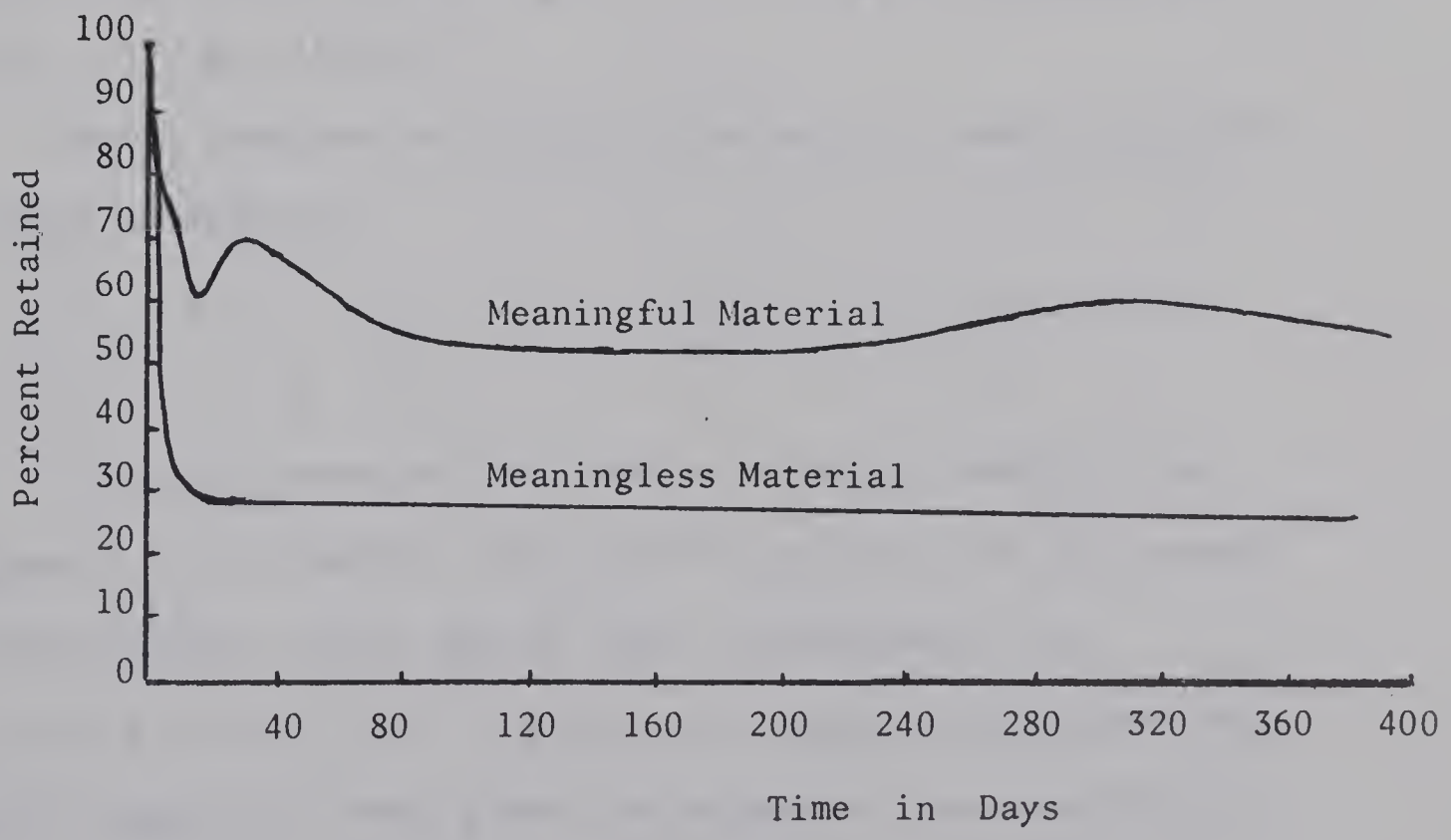


Figure 2

Later in the same summary of the views of educators, Bruner states,

> Knowledge one has acquired without sufficient structure to tie it together is knowledge that is likely to be forgotten. An unconnected set of facts has a pitiably short half-life in memory. (14, p. 31)

Frederick McDonald expresses the view held by many educational psychologists when he asserts,

> The hypothesis that individuals try to make sense out of what they are experiencing would suggest a hypothesis that the introduction of an organizing principle into the study of new material would be likely to facilitate both learning and remembering this material. This hypothesis has been supported in a number of experimental studies. (15, pp. 191-192)

In support of his statement McDonald refers to Tyler's study in college biology (9, loc. cit.) which is later described in this chapter, and to one by Katona which can briefly be described as follows: (16, pp. 187-190)

Katona required two groups of subjects to learn the following series of numbers:

5	8	1	2	1	5	1	9	2	2	2	6
2	9	3	3	3	6	4	0	4	3	4	7

The first group was told that a principle underlay the arrangement of the numbers. Most of the subjects soon discovered that the principle was to add 3, then 4 alternately, i.e. $5 + 3 = 8$, $8 + 4 = 12$, $12 + 3 = 15$, etc. The other group was to learn the numbers by rote, given the suggestion that a rhythmical

grouping might help. The subjects were tested shortly after the experiment and then again three weeks later. Results were as shown:

	Subjects who reproduced correctly		Subjects who made 19 or more errors	
	CLASS I (Understanding)	CLASS II (rote)	CLASS I (Understanding)	CLASS II (rote)
Half-hour after learning	38%	33%	10%	7%
Three weeks later	23%	0%	15%	74%

Note: There were 29 subjects in Class I and 30 in Class II for the original tests. Of these, 26 and 23, respectively, were present for the retests.

This among other experiments of Katona demonstrates the importance of having some organizing principle to facilitate retention. Katona summarizes his own views as follows:

> The question 'what do we retain' should not be answered by 'raw facts (concrete individual items) and words.' We retain either more than facts and words or, as in the case of certain types of learning, something different, namely, whole-qualities representing a structure, a principle, an essence, or combinations of principles, individual items, and words. (16, p. 230)

Deese relates an account of a study in which students were required to learn a 1000-word article. Some of the students were tested immediately after the learning, and others were tested after various periods of delay. Retention of specific statements showed a decline with time, but there was practically no decline at all of memory for the "sense" of the article. (17, p. 151)

Gagné and Bassler concluded after a study of retention in geometry that,

> ... retention of the capability of performing a final task appears to be better than retention of the subordinate learning sets which originally contribute to the learning of that capability. Some of these learning sets are forgotten, even though performance of the total task remains at a level as good as that originally attained. (3, loc. cit.)

Many studies have seemed to indicate that very little factual material taught by conventional methods is retained. One such study described by Novak involved 1,354 students in Kansas high schools. (18, pp. 241-244) With the Nelson Biology Test as the measuring instrument the average mean score of freshman biology students showed only about 10% gain from fall pre-test, administered before beginning the course, to spring post-test, administered about 14 weeks after completing the course. There were individual variations, but the evidence is that students taught by drill on textbook information, which was the standard method of instruction in the schools studied, showed very little permanent gain inknowledge of biological facts.

Primarily to test the relationship between retention of subject-matter and its method of presentation, Kastrinos carried out a very interesting study with students enrolled in a college-preparatory course in biology in Glenbard High School, Lafayette, Indiana. (19, pp. 487-491) The 78 students involved were taught using what was called a "principles critical thinking" approach.

One of the main goals of the course was to teach the interrelationships between the material as the course progressed. Students were encouraged to relate the current material to material which had been previously studied. Students were aware from the outset that they would be required to write an examination on the entire year's work. Testing was done by means of the Nelson Biology Test, the same instrument used in the Kansas schools by Novak. (18, loc. cit.) Pre-test was given immediately before commencing the course, post-test immediately after its completion, and retention test two years later. Results are shown in the following table:

PRE-TEST, POST-TEST, RETENTION TEST MEANS
on Nelson Biology Test

Test	Mean Score	Difference	t-Value
Pre-Test	35.89		
Post-Test	51.07	+15.18	22.34**
Pre-Test	35.89		
Retention	48.52	+12.63	11.18**
Post-Test	51.07		
Retention	48.52	-2.55	3.01*

* Significant at the 5% level
** Significant at the 1% level

In view of results which he obtained, Kastrinos maintains that even factual material, if it is taught so that it is meaningful to the student, is retained much better than is the case if dependence is on rote memory. He holds that there is a relationship between the development of conceptual schemes and factual material, that the job of the science teacher is to make material more meaningful and to dispel the idea that factual material need not be learned.

An investigation of retention in high school chemistry was carried out by F. P. Frutchey, using as his subjects the students in three high schools in Ohio. (20, pp. 34-37) Tests designed as a cooperative project with three chemistry teachers were administered at the beginning of the course, at the end, and again a year later. Testing for five different objectives, results obtained were as follows:

RETENTION IN PERCENTAGE OF GAIN MADE DURING THE COURSE

	Girls	Boys	Both
Selection of facts	64	93	84
Application of principles	93	91	92
Terminology	46	75	66
Symbols, formulas, valence	65	73	70
Balancing equations	76	70	72
Total	67	87	81

Frutchey notes that, of the five objectives, retention in knowledge of chemical terms was the lowest, while on the other hand retention was highest in the application of facts and principles.

A classic study in which a comparison was made of retention of material in various categories was made by Tyler in the field of college biology. (9, pp. 133-142)

His subjects were 82 students who studied elementary zoology at Ohio State University during the year 1930-31, and who, "both with reference to average marks and spread, were typical of those enrolled in the elementary zoology course." Fifteen months after completing the course they were retested, with results shown as follows:

THE RELATIVE RETENTION OF VARIOUS MATERIALS PRESENTED IN A COLLEGE COURSE IN ELEMENTARY ZOOLOGY

Types of Exam. Exercises	Mean Score at Beginning of Course Fall, 1930	Time of Examination Spring, 1931	June 1932	Percentage of Gain made in Course lost by June, 1932
Naming animal structures in diagrams	20	62	31	77
Identifying technical terms	20	83	67	26
Recalling information: Structures performing functions	13	39	34	21
Other facts	21	63	54	21
Applying principles to new situations	35	66	65	.07*
Interpreting new experiments	30	57	65	25*

*Percentages thus marked are permanent gains.

Tyler's finding that specific information is most quickly forgotten, while information of more general application is more permanent is of great importance. It is a finding which has been borne out in many other fields as well as in biology.

In another retention study conducted with ninth grade pupils of general science in two high schools in North Carolina, Tyler found that, "the greatest loss was in information about science, whereas there was little or no loss in the ability to explain everyday phenomena and the ability to generalize from given facts."(10, pp. 490-492)

Another study along lines very similar to that of Tyler was done by James E. Wert, extending in time from 1930 to 1934, and involving students who took elementary zoology at Ohio State University. (11, pp. 136-140) Testing was done with equivalent forms of instruments developed under the direction of R. W. Tyler. Each of the subjects, none of whom had elected further courses in biology, was given a pre-test, a course final, and three retests at one-year intervals. Results of this investigation are shown in the following table:

RETENTION OF COURSE GROWTH IN ELEMENTARY ZOOLOGY
EXPRESSED IN PERCENTAGES

Objectives	End of Years One	Two	Three
Naming animal structures	23	18	10
Stating function of structures	59	47	41
Terminology	57	54	51
Other facts (principles, generalizations)	70	68	49
Interpreting new experiments	111	114	119
Applying principles to new situations	127	154	158

It is noted from the above table that the findings of Wert strongly substantiated those of Tyler. While knowledge of specific information showed a decline, there was no loss, but in fact an actual gain, in the ability to interpret new experiments and to apply principles to new situations. This indicates that the ways of thinking which are applicable to new experiments and situations in a particular subject are carried on and developed in one's total education even after study of that specific subject has been discontinued.

Summary

Since the great weight of evidence shows that retention of material depends upon the extent of its integration into a structural

pattern, and that single items of information, especially if not integrated into a larger structure, are soon forgotten, it appears reasonable to expect that retention in the higher categories of Bloom's Taxonomy will be better than in the lower. The abilities required for such tasks as analysis, synthesis, and evaluation would appear to correspond to those which were found to be best retained in most of the studies considered. Attainment in these higher categories depends on perception of relationships. The bulk of evidence indicates that relationships when once perceived are remembered much better than mere information.

The keynote of all the literature examined is that isolated, unrelated items of information are soon forgotten, but that learnings that fit as parts of integrated wholes so that they are in a meaningful context are much better retained. It may almost be said that there is a direct relationship between the degree of retention of learned material and the extent of its integration into structural patterns. Meaningfulness is of prime importance in retention.

CHAPTER III

DESIGN OF THE STUDY

INTER-SYSTEM TESTING PROGRAM

Data for this study were obtained by administering a test in June, 1966, and the same test again in September of the same year, to all students who were enrolled in Science 20, and who were not taking P.S.S.C. Physics, (21) in the school divisions and counties included in an organization called the "Inter-System Testing Organization" in north-eastern Alberta. This organization included the counties of Smoky Lake, Thorhild, Two Hills, and St. Paul, and the school divisions of Bonnyville, Lac La Biche, and Sturgeon.

At a meeting held in Smoky Lake in November, 1965, of superintendents and other representatives from all the school divisions and counties participating in the program of the Inter-System Testing Organization, the writer of this thesis volunteered to supply the required test in Science 20 to all schools which were using the text, Physics for Secondary Schools, by Eubank, Ramsay and Rickard (22), and which had not switched over to P.S.S.C. Physics.(21) It was explained to all present at the meeting that the physics section, with follow-up retest, would be used for a study in retention, which would constitute the basis for a master's thesis in

education. All superintendents of the participating school systems gave their approval of the study, and all agreed to encourage the co-operation of the principals and teachers who would be involved.

THE TEST

A test was prepared by the writer of this thesis. It consisted of a chemistry section, and the physics section which constituted the testing instrument herein described. The physics test, which in its final form consisted of fifty multiple-choice items, is shown in Appendix A.

Evaluation and Selection of Test Items before Test-Retest

As originally constructed, the physics test contained sixty-five items. All test items were carefully considered and discussed by the writer and his committee of advisers at a group meeting, and each item was assigned to the category of Bloom's Taxonomy in which it was agreed, by majority consensus, to fit best. To determine its reliability and the validity of its items, the test was administered immediately before the Easter holidays, and as a retest immediately after the holidays, to all students taking Science 20 in Lamont School Division, which is outside the Inter-System Testing Organization. This was arranged through the kindness of the superintendent and science teachers.

Ninety-four students, which number, except for three absentees, constituted the total enrolment in Science 20 in the three high schools of the division, wrote both test and retest. (Item analysis is shown in Appendix B.)

After deletion of items which showed a biserial correlation of 0.15 or less on the first administration, fifty-two items remained. Of these, two more were deleted before final processing in the main study because it was considered that there was some ambiguity in their wording.

Although it would have been desirable to exclude items with a difficulty index of less than 0.2, this was not done as it would have left some categories with too few items.

Test-retest reliability of the final 50-item test as determined by administration of these 50 items to the 94 students was 0.809.

Classification of the 50 items according to categories of Bloom's Taxonomy is shown in Table I.

INTER-SYSTEM TEST ADMINISTRATION

All inter-system test papers were printed and distributed to the schools requiring them under arrangements made by the superintendent of Sturgeon School Division, who was co-ordinator of the testing program. With the key for marking the physics section of Science 20 was a brief note to the teacher explaining the reason for

TABLE I

Classification of Test Items

Bloom's Category	
1.1	2, 4, 6, 8, 14, 17, 22, 31, 46
1.2	1, 12, 13, 15, 20, 37, 41
1.3	7, 11, 21, 33, 42, 43
2	3, 9, 18, 26, 32, 36, 38, 39
3	10, 24, 27, 28, 30, 40, 44, 49
4	5, 16, 29, 34, 35
5	19, 45, 48, 50
6	23, 25, 47

Note: Its category according to Bloom's Taxonomy is shown after each test item in Appendix A. Deleted items are shown after the 50-item final test in Appendix A.

a request that answer sheets be returned to the superintendent of the division or county for forwarding to the author of the test. (See Appendix A.)

Excellent co-operation was received from teachers, principals, and superintendents. Test with matching retest papers were received from a total of fifteen schools. Class sizes ranged from four to twenty-one students. Date of the test was June 16, 1966, and of retest was September 7, 1966.

A final check was made with principals regarding any students who had taken correspondence or other formal instruction to improve their standing in Science 20 during the summer. Since only one student had taken such instruction, it was necessary to remove only one set of papers for this reason.

Test-retest results are given and discussed in Chapter IV.

OTHER DATA ON STUDENTS

Grade IX Ability Percentile Ratings

The Grade IX records at the Department of Education were examined to obtain for all students included in the study their percentile ratings on the Grade IX Ability Test. For all but six students these were located. Of these six, one had been granted Grade IX pass standing by the Special Cases Committee of the Department of Education, one was an adult student who had taken Grade IX many years before, and the others had taken Grade IX outside the

Province, or at least outside the area covered by the Inter-System Testing Organization. The papers of these six students were discarded from the sample.

THE SAMPLE

For a total of 170 students complete data were available. It was decided that inclusion of all 170 of these would constitute a reasonably representative sample of students enrolled in Science 20 in the geographic area covered by the Inter-System Testing Organization's program. Therefore all 170 subjects were included in the sample.

TECHNIQUES OF ANALYSIS

The statistical procedures chosen for analysis of data were as follows:

1. t-Tests where comparison of two means was required,
2. Analysis of variance wherever the effect of two or more factors on means was to be considered.

For these analyses all data from test papers were transferred to punch cards and processed by computer at the Department of Computing Science, University of Alberta, Edmonton.

CHAPTER IV

ANALYSIS, INTERPRETATION, AND DISCUSSION OF RESULTS

The Test as a Whole

Considering performance of the student group as a whole, the mean score dropped from 23.806 on the June test to 22.300 on the September retest - a reduction of 1.51 points. Although a reasonably normal distribution was obtained on both test and retest, attainment on both was rather disappointing. The explanation is offered that since physics is taught during the first half of the year in all schools, and since few find time for more than a very brief review, it is likely that much forgetting of course material took place before the June test. It is probable that the gap between test and retest performances would appear considerably larger if the first test could have been given immediately after completing the course.

A frequency distribution of test and retest scores, with cumulative frequencies, and measures of central tendency, is shown in Table II.

The same information is illustrated graphically in a frequency polygon in Figure 3, and a cumulative frequency ogive in Figure 4.

Subtests

As mentioned in Chapter I, the study here described was designed to investigate and compare the amounts of knowledge, as

TABLE II

Frequency Distribution of Test and Retest Scores

Score	Frequency Test	Retest	Cumulative Frequency Test	Retest
9	1	0	1	0
10	1	0	2	0
11	2	4	4	4
12	2	3	6	7
13	1	3	7	10
14	5	6	12	16
15	6	6	18	22
16	3	10	21	32
17	6	8	27	40
18	4	9	31	49
19	9	6	40	55
20	6	11	46	66
21	14	12	60	78
22	14	10	74	88
23	9	16	83	104
24	16	13	99	117
25	9	10	108	127
26	6	5	114	132
27	10	4	124	136
28	7	8	131	144
29	8	5	139	149
30	6	6	145	155
31	4	3	149	158
32	5	0	154	158
33	6	4	160	162
34	3	2	163	164
35	2	1	165	165
36	1	1	166	166
37	1	3	167	169
38	1	0	168	169
39	1	0	169	169
40	1	1	170	170

Measures of Central Tendency

	June Test	September Retest
Mean	23.806	22.300
Median	23.125	21.700
Mode	24	23

Frequency Polygon of Test and Retest Scores

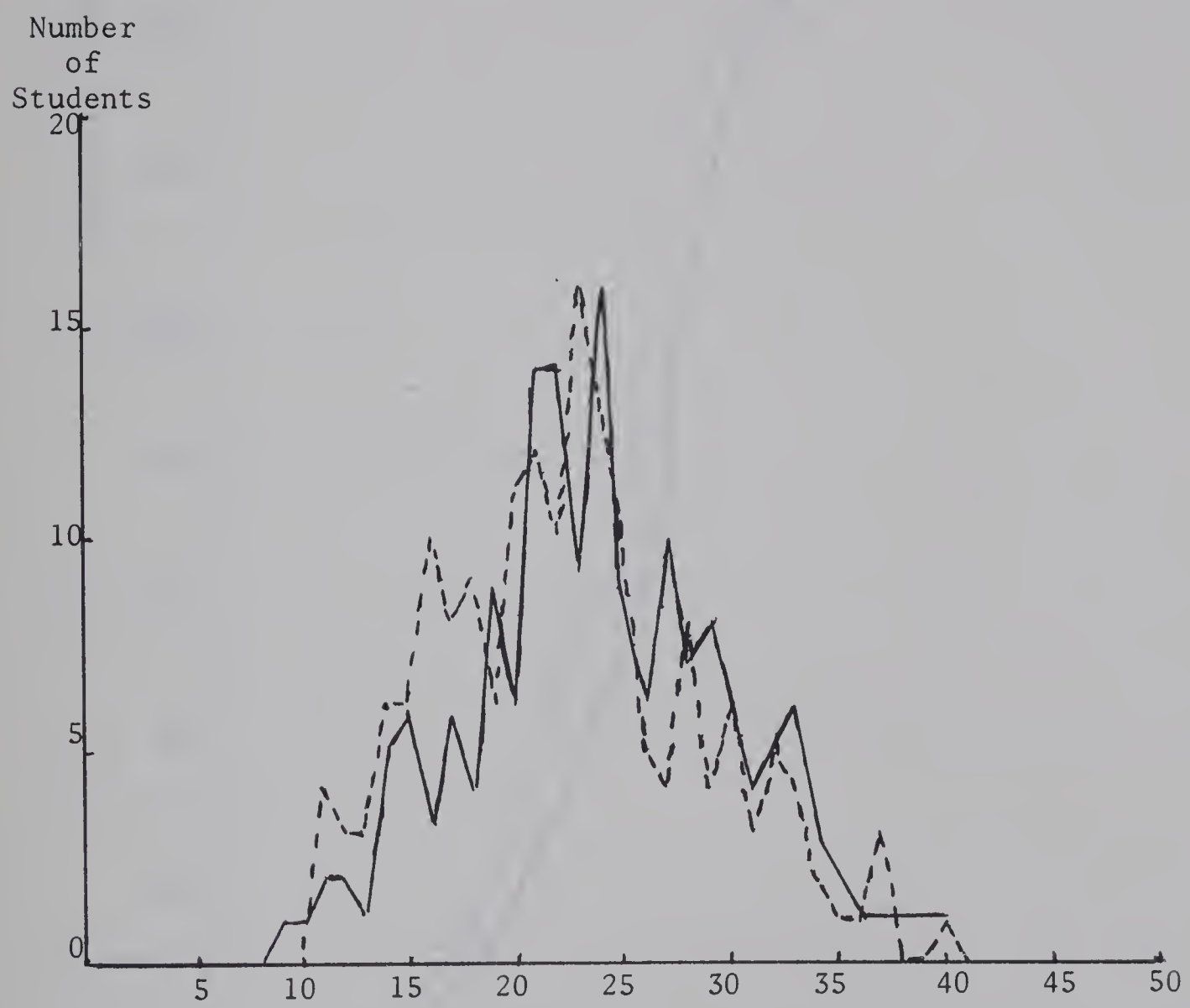


Figure 3

Frequency Ogive of Test and Retest Scores

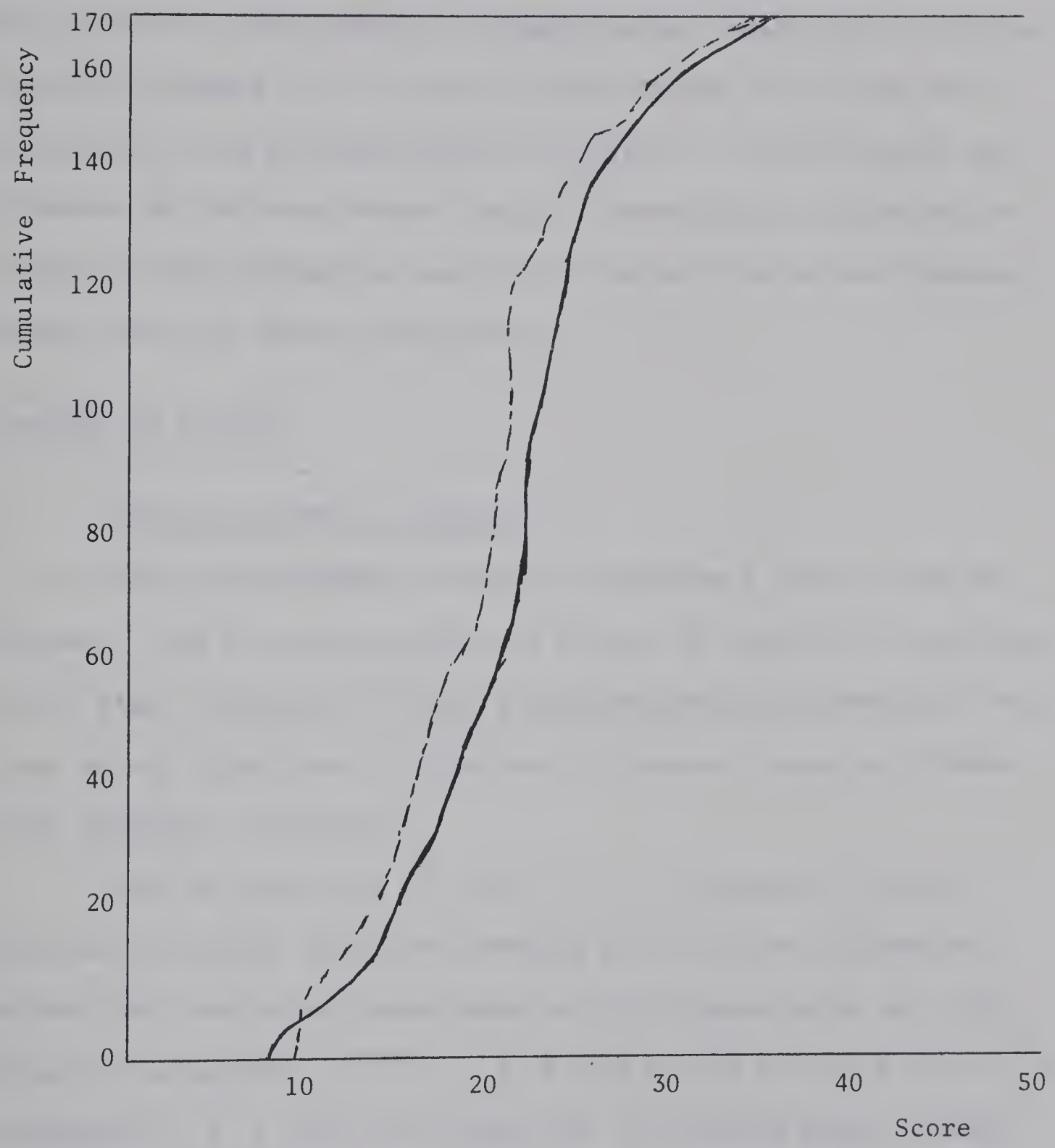
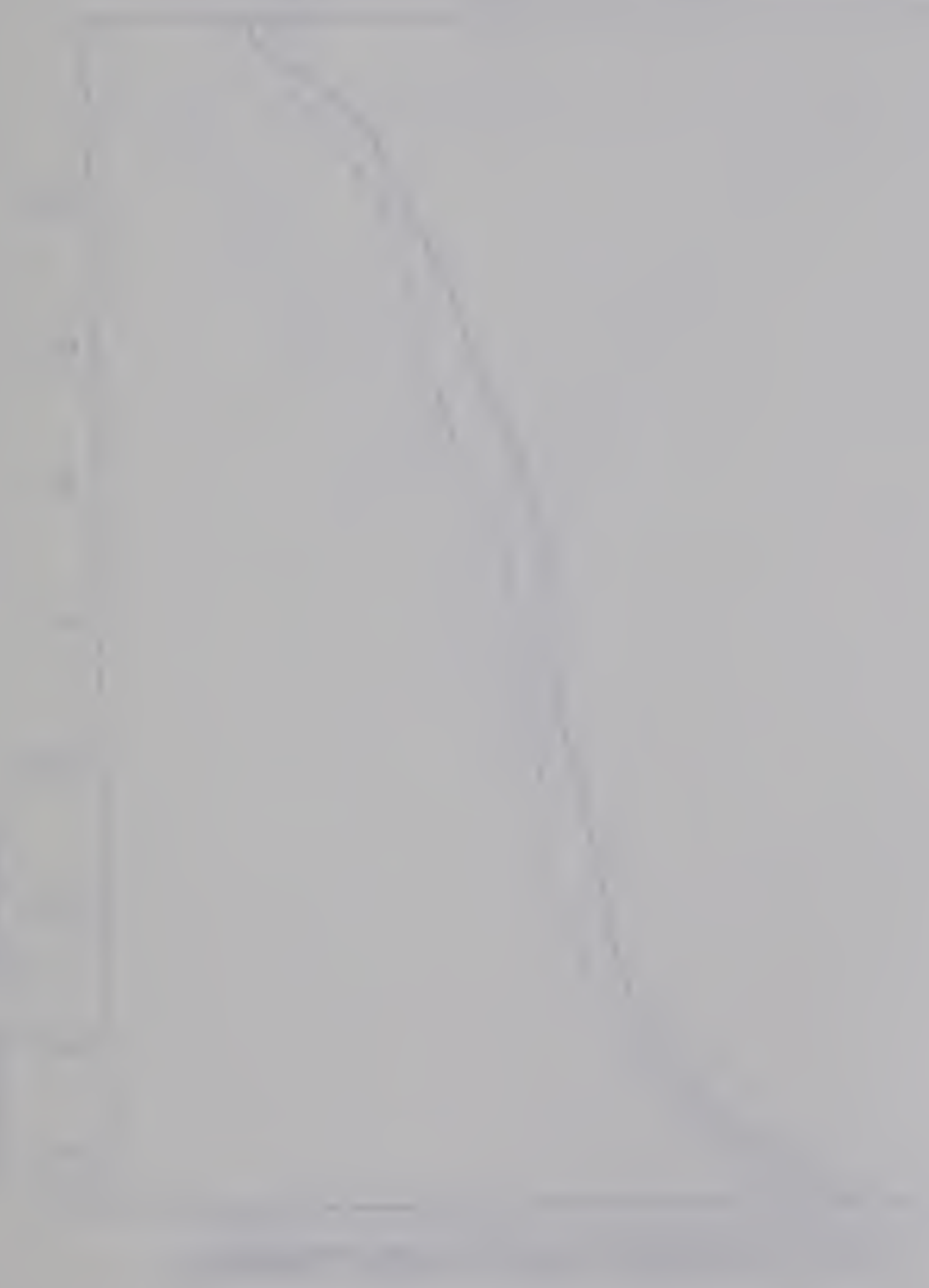


Figure 4



classified in the different categories of Bloom's Taxonomy, retained for a period of three months by students after completing the physics section of Science 20. In line with this design, test items were classified as was previously shown in Table I. Test and retest performances of the total student group in these single categories, in groups of these categories, and on the test as a whole were compared using t-tests as shown in Table III.

Findings of t-Tests

Answer to Problem 1, Part A

The question asked in Chapter I, Problem 1, Part A, was as follows: When the subject-matter of Science 20 Physics is classified in the eight categories of Bloom's Taxonomy previously described, will there be any significant differences in students' retention between these different categories?

From an inspection of Table III, it is apparent that the question just asked can now be answered partly in the affirmative. Between test and retest means there are differences which are significant in categories 1.1, 1.2, 1.3, 3, and on the test as a whole. In categories 2, 4, 5, and 6 no significant differences appear between test and retest means.

Recalling the descriptions of Bloom's categories, it is seen that forgetting is significant in knowledge of specifics, knowledge of ways and means of dealing with specifics, and knowledge of universals

and abstractions. The explanation is offered that material in these three categories is lost because it has not been put into a meaningful context or structure in the student's mind. Most of the literature examined in Chapter II showed that such material is most quickly forgotten.

The problems in application of knowledge in the test given in this study called in most cases for the student to possess the knowledge to be applied - therefore forgetting appeared significant in category 3, contrary to what might have been expected in view of the findings of Frutchey (20) and others. The reason for this low performance seems apparent in such items as No. 10, which reads as follows:

10. A hoist will raise a ton of ore 110 feet in one minute. The horsepower rating of the hoist would be

    (a) 1.3
    (b) 6.7
    (c) 11.1
    (d) 55.2

It is apparent that the student must possess the factual information of the number of pounds in a ton and the rate of work which equals one horsepower. It seems likely that the apparent loss in application of knowledge was actually a manifestation of loss of the knowledge to be applied.

The lack of significant loss in categories 2, 4, 5, and 6 can be explained by the proposition that comprehension, analysis, synthesis, and evaluation depend on the deeper understandings and cognitive

abilities which result from a structuring of knowledge. These abilities have been shown by many of the studies quoted in Chapter II to persist with very little diminution, or even to increase with time.

Table III shows that, in the higher categories of Bloom's Taxonomy, scores on the average were quite low. This can be interpreted as showing that only a small proportion of the class had developed sufficient of the cognitive skills and abilities required to cope successfully with these more sophisticated problems. However, the evidence is that these skills and abilities, when developed, tend to persist. They are not lost to memory as is factual knowledge.

Answer to Problem 1, Part B

A restatement of the question asked in Problem 1, Part B, in Chapter I is as follows: When classification of subject-matter is in three groups of categories of Bloom's Taxonomy as follows: Group I, Knowledge (including specifics, ways and means of dealing with specifics, and universals and abstractions), Group II, Comprehension and Application, and Group III, Analysis, Synthesis, and Evaluation, will there be any significant differences in students' retention between these different groups of categories? (Such grouping was designed to emphasize the comparison between retention in the knowledge categories and that in the middle, and especially the upper, group of cognitive skills and abilities.)

TABLE III

Comparison of Test and Retest Means Using t-Tests

Bloom's Category	1.1	1.2	1.3	2	3	4	5	6	1.1,1.2 & 1.3	2 & 3	4,5 & 6	Entire Test
Number of Items in Category	9	7	6	8	8	5	4	3	22	16	12	50
Test Mean	5.771	3.624	2.688	4.088	3.488	1.953	1.235	0.959	12.182	7.576	4.147	23.806
Retest Mean	5.512	3.347	2.300	3.947	3.200	1.900	1.176	0.918	11.159	7.147	3.994	22.300
Test S. D.	1.549	1.401	1.386	1.467	1.770	1.217	0.883	0.857	3.120	2.665	1.975	6.171
Retest S. D.	1.554	1.325	1.319	1.621	1.521	1.196	0.923	0.815	2.941	2.654	1.960	6.107
t-Value Obtained (df=169)	2.114	2.541	3.902	1.127	2.132	0.459	0.795	0.646	4.906	2.282	1.008	4.556
Probability	<.05	<.02	<.001	*	<.05	*	*	*	<.001	<.05	*	<.001

* Non-significant

t-Value required for significance:

1.960	2.326	2.576	3.291
.05	.02	.01	.001

The question stated above can now be answered by inspecting Table III. The difference between test and retest means in the group consisting of 1.1, 1.2, and 1.3 is significant beyond the .001 level of confidence. In the group consisting of categories 2 and 3, the .05 level of confidence is exceeded. No significant difference appears between test and retest means in the group of categories 4, 5, and 6.

These findings agree with, and in effect, summarize, what was found by examining retention in each single category. Forgetting is highly significant in the combined categories of knowledge, i.e., specifics, ways and means of dealing with specifics, and universals and abstractions.

The increase in significance of loss in the combined categories of 2 and 3 over that shown in 3 alone would indicate that some contribution is made to this probability by a loss in comprehension as well as in application.

Even with categories combined, no loss is apparent in ability to analyze, synthesize, and evaluate, as shown by a t-value which is still well below a significant level for the combination of categories 4, 5, and 6. This adds to the weight of evidence that these higher abilities are retained even when the factual information with which they were first associated has diminished.

RETENTION AS DETERMINED BY ANALYSIS OF VARIANCE ON THE BASIS OF THREE STUDENT GROUPS

Groups on Basis of June Test

To determine what relationship exists between a student's placement in class and his retention in the various test categories, as well as in the total test, the entire sample of 170 students was divided into three groups on the basis of June test scores. These groups were, as nearly as possible, equal in size. They were made up as follows:

Student Groups on Basis of June Test

Group Number	Number of Subjects in Group	Range of Scores
1	60	9 - 21
2	54	22 - 26
3	56	27 - 40

Using these groups, a two-way analysis of variance was done to compare achievement on June test with that of the same group of students on the September retest in each of the various categories and on the test as a whole. Because the groups were not quite equal in size, the "unweighted means" approach was used. (23, pp. 241 and 302) Results of the analysis of variance are shown in Table IV.

In Table IV, the main effect "B" represents the comparison of test and retest means for the entire group of 170 students. It conveys with specific probability calculations the information which has been arrived at by t-tests in the individual categories and on the test as a whole.

TABLE IV

Two-Factor Analysis of Variance with Repeated Measures on Factor "B"
With Three Groups on Basis of June Test

Bloom's Category	Group No.	Number in Group	Test Mean	Retest Mean	Source of Variation	Sum of Squares	Degrees of Freedom	Mean Square	F	Probability
	1	60	4.80	4.80	Within Subjects	221.000	170			
1.1	2	54	5.76	5.39	"B" Main Effects	6.015	1	6.015	4.740	0.0309
	3	56	6.82	6.39	"A x B" Interaction	3.059	2	1.529	1.205	0.3022
					"B" x Subjects Within Groups	211.926	167	1.269		
	1	60	2.80	2.88	Within Subjects	176.500	170			
1.2	2	54	3.56	3.20	"B" Main Effects	6.940	1	6.940	7.111	0.0084
	3	56	4.57	3.98	"A x B" Interaction	6.576	2	3.288	3.369	0.0368
					"B" x Subjects Within Groups	162.984	167	0.976		
	1	60	1.67	1.70	Within Subjects	155.000	170			
1.3	2	54	2.57	2.13	"B" Main Effects	13.502	1	13.502	17.092	0.0001
	3	56	3.89	3.11	"A x B" Interaction	9.573	2	4.786	6.059	0.0029
					"B" x Subjects Within Groups	131.926	167	0.790		
	1	60	3.12	3.13	Within Subjects	227.000	170			
2	2	54	4.39	3.89	"B" Main Effects	1.892	1	1.892	1.437	0.2324
	3	56	4.84	4.87	"A x B" Interaction	5.220	2	2.610	1.982	0.1409
					"B" x Subjects Within Groups	219.891	167	1.317		
	1	60	2.22	2.42	Within Subjects	269.500	170			
3	2	54	3.39	3.00	"B" Main Effects	7.690	1	7.690	5.144	0.0246
	3	56	4.95	4.23	"A x B" Interaction	12.145	2	6.073	4.062	0.0189
					"B" x Subjects Within Groups	249.664	167	1.495		
	1	60	1.35	1.65	Within Subjects	191.500	170			
4	2	54	1.94	1.83	"B" Main Effects	0.326	1	0.326	0.295	0.5877
	3	56	2.61	2.23	"A x B" Interaction	6.544	2	3.272	2.960	0.0545
					"B" x Subjects Within Groups	184.630	167	1.106		
	1	60	0.82	0.93	Within Subjects	79.000	170			
5	2	54	1.19	1.06	"B" Main Effects	0.346	1	0.346	0.748	0.3885
	3	56	1.73	1.55	"A x B" Interaction	1.416	2	0.708	1.531	0.2193
					"B" x Subjects Within Groups	77.238	167	0.463		
	1	60	0.65	0.63	Within Subjects	58.500	170			
6	2	54	0.91	0.94	"B" Main Effects	0.141	1	0.141	0.408	0.5238
	3	56	1.34	1.20	"A x B" Interaction	0.482	2	0.241	0.696	0.4999
					"B" x Subjects Within Groups	57.876	167	0.463		
	1	60	17.42	18.15	Within Subjects	1762.000	170			
Entire	2	54	23.70	21.44	"B" Main Effects	208.532	1	208.532	26.499	0.0000
Test	3	56	30.75	27.57	"A x B" Interaction	236.770	2	118.385	15.015	0.0000
					"B" x Subjects Within Groups	1316.687	167	7.884		

"A x B" represents the interaction between the main effect and the effect of grouping, i.e., it shows whether any significant differences in retention are apparent between different groups in any category or on the test as a whole.

Findings of Analysis of Variance With Three Groups on Basis of June Test

With subjects divided into three groups on the basis of attainment in the June test, as shown in Table IV, it is apparent that results of the analysis of variance for main effects are, as would be expected, in full agreement with conclusions drawn from the t-tests which have already been referred to. Probabilities arrived at by analysis of variance are shown in Table V.

It is seen that once again significant differences are shown between test and retest means in categories 1.1, 1.2, 1.3, and 3, while differences are non-significant in categories 2, 4, 5, and 6. On the test as a whole the difference between means is again shown to be highly significant, which is to be expected, since it is contributed to by categories 1.1, 1.2, 1.3, and 3.

It is apparent that interaction between the main effect and the effect of grouping reaches significant levels in categories 1.2, 1.3, and 3, and on the test as a whole. Probabilities are summarized in Table VI.

TABLE V

Analysis of Variance for Main Effect "B"

Bloom's Category	Level of Confidence for Significance Analysis of Variance	* t-Test
1.1	.0308	$<.05$
1.2	.0084	$<.02$
1.3	.0001	$<.001$
3	.0246	$<.05$
Entire Test	.0000	$<.001$

* t-Test levels of confidence are shown for comparison.

TABLE VI

Interaction Between Group Placement and Retention

With Three Groups on Basis of June Test

Bloom's Category	Level of Confidence "A x B" Interaction
1.2	$<.05$
1.3	$<.05$
3	$<.01$
Entire Test	$<.001$

Answer to Problem 2 (a) (i)

From the results of the analysis of variance just considered, an answer can be supplied to the question of Problem 2 (a) (i), which asked: Are there any significant differences between different student groups in their retention of subject-matter of Science 20 Physics in the various categories of Bloom's Taxonomy when the groups are formed on the basis of June test scores?

The answer is that there are differences which are significant beyond the 5% level of confidence in categories 1.2 and 1.3, and beyond the 1% level in category 3. For the entire test, the difference in retention between the different groups is significant beyond the 0.1% level of confidence.

While one might expect that the proportionate loss would be less in the higher attainment groups than in the lower, an examination of cell means does not support this expectation. If the expectation was reasonable in the first place, then its lack of fulfilment may be partly explained by the assumption that different students vary in their amount of preparation for the test. Some may have "crammed" material which will soon be forgotten. For this reason their scores may reasonably be expected to drop by retest time. This could account for the greater loss shown from test to retest by the higher attainment groups. At any rate, the conclusion must be accepted that significant differences in retention between groups was apparent because

there was, in general, more forgetting by the upper and middle group than the lower, when groups were formed on the basis of June test scores.

It appears that, of the students whose temporary grasp of material placed them in the upper or middle third of the class in June, their mastery of principles and methods was less secure than their mastery of other material, thus resulting in a significant reduction in their attainment from test to retest in ways and means of dealing with specifics, universals and abstractions, and application.

Groups on Basis of September Retest

If some students place in a higher achievement group because of much "cramming," then it seems reasonable to expect that these students will revert to their true level in a short time after the examination is over. A more reliable picture of a student's true attainment, it would appear, can be obtained by grouping according to scores on the retest.

In line with this thinking, students were divided into three groups, as nearly equal as possible, on the basis of September retest marks as follows:

Student Groups on Basis of September Retest

Group Number	Number of Students	Range of Scores
1	55	11 - 19
2	62	20 - 24
3	53	25 - 40

With students thus grouped on the basis of September retest scores, a two-way analysis of variance was carried out as was done previously with groupings on the basis of June test scores. Details of this analysis are shown in Table VII.

Findings of Analysis of Variance With Three Groups on Basis of September Retest Scores

With regard to main effects, it is seen that, as would be expected, there is full agreement with the t-tests and with the analysis of variance which used June test groups. Levels of confidence are the same in all cases of significance as shown previously in Table V.

Regarding interaction, there are significant differences between groups in their retention in category 2 and on the test as a whole.

Answer to Problem 2 (a) (ii)

The question of Problem 2 (a) (ii) asked: Are there any significant differences between different student groups in their retention of subject-matter in the various categories of Bloom's

TABLE VII

Two-Factor Analysis of Variance with Repeated Measures on Factor "B"
With Three Groups on Basis of September Retest

Bloom's Category	Group No.	Number in Group	Test Mean	Retest Mean	Source of Variation	Sum of Squares	Degrees of Freedom	Mean Square	F	Probability
	1	55	4.96	4.40	Within Subjects	221.000	170			
1.1	2	62	5.97	5.66	"B" Main Effects	5.383	1	5.383	4.300	0.0396
	3	53	6.38	6.49	"A x B" Interaction	6.589	2	3.295	2.632	0.0749
					"B" x Subjects Within Groups	209.027	167			
	1	55	2.96	2.49	Within Subjects	176.500	170			
1.2	2	62	3.48	3.29	"B" Main Effects	6.573	1	6.573	6.521	0.0116
	3	53	4.47	4.30	"A x B" Interaction	1.600	2	0.800	0.794	0.4538
					"B" x Subjects Within Groups	168.324	167	1.008		
	1	55	1.62	1.35	Within Subjects	155.000	170			
1.3	2	62	2.87	2.34	"B" Main Effects	12.318	1	12.318	14.522	0.0002
	3	53	3.58	3.25	"A x B" Interaction	1.024	2	0.512	0.604	0.5479
					"B" x Subjects Within Groups	141.657	167	0.048		
	1	55	3.64	2.60	Within Subjects	227.000	170			
2	2	62	3.66	3.94	"B" Main Effects	1.994	1	1.994	1.735	0.1896
	3	53	5.06	5.36	"A x B" Interaction	32.991	2	16.496	14.347	0.0000
					"B" x Subjects Within Groups	192.016	167	1.150		
	1	55	2.60	2.05	Within Subjects	269.500	170			
3	2	62	3.48	3.18	"B" Main Effects	6.829	1	6.829	4.412	0.0372
	3	53	4.42	4.42	"A x B" Interaction	4.211	2	2.106	1.360	0.2593
					"B" x Subjects Within Groups	258.460	167	1.548		
	1	55	1.67	1.55	Within Subjects	191.500	170			
4	2	62	1.84	1.73	"B" Main Effects	0.200	1	0.200	0.175	0.6761
	3	53	2.38	2.47	"A x B" Interaction	0.868	2	0.434	0.380	0.6840
					"B" x Subjects Within Groups	190.433	167	1.140		
	1	55	0.96	0.76	Within Subjects	79.000	170			
5	2	62	1.16	1.10	"B" Main Effects	0.272	1	0.272	0.586	0.4449
	3	53	1.60	1.70	"A x B" Interaction	1.225	2	0.612	1.320	0.2700
					"B" x Subjects Within Groups	77.503	167	0.464		
	1	55	0.55	0.53	Within Subjects	55.500	170			
6	2	62	0.97	0.90	"B" Main Effects	0.136	1	0.136	0.391	0.5329
	3	53	1.38	1.34	"A x B" Interaction	0.030	2	0.015	0.044	0.9573
					"B" x Subjects Within Groups	58.333	167	0.349		
	1	55	18.96	15.73	Within Subjects	1762.000	170			
Entire	2	62	23.44	22.13	"B" Main Effects	189.142	1	189.142	22.270	0.0000
Test	3	53	29.26	29.32	"A x B" Interaction	154.517	2	77.259	9.096	0.0002
					"B" x Subjects Within Groups	1418.375	167	8.493		

Taxonomy when the groups are formed on the basis of September retest scores in Science 20 Physics?

The answer to this question is that significant differences between groups showed in their retention of material in category 2, and on the test as a whole, both being at a level beyond 0.1% probability.

An examination of cell means shows that there was a general tendency for the top attainment group to retain a larger proportion of the material learned in each category than the middle or lower group. One exception occurs in category 2, where the middle group surpassed both others in the proportion retained. Further examination of means shows that there was even an apparent slight gain from test to retest in categories 1.1, 2, 4, 5, and on the test as a whole by the top attainment group. For the lowest group, retest means were in all cases lower than test means.

The gains noted are considered to be too slight to be elaborated upon. Probably the most valid comment would be to say that students of upper ability showed no loss in any category. Their superior mastery of course material, apparent after an interval of three months, enabled them to surpass others significantly in comprehension and in total retention.

Groups on Basis of Grade IX Ability Rating

The sample of 170 students was again divided into three groups, as nearly equal as possible, this time on the basis of Grade IX ability percentile ratings. The makeup of groups was as follows:

Group Number	Number in Group	Range of Percentile Ratings
1	59	6 - 47
2	56	49 - 73
3	55	75 - 99

A two-way analysis of variance was done with this classification to see whether any significant relationships would be apparent between ability groups and retention in any of the categories of Bloom's Taxonomy. Results of this analysis are shown in Table VIII.

Findings of Analysis of Variance With Three Groups on Basis of Grade IX Ability Percentile Rating

As with both the previous analyses of variance, there is perfect agreement with results of t-tests regarding levels of confidence for significance of difference between test and retest means for the entire group, i.e., main effects. These levels are shown in the following summary of information which has previously been given in Table V.

Bloom's Category	Level of Confidence for Significance
1.1	$< .05$
1.2	$< .02$
1.3	$< .001$
3	$< .05$
Entire Test	$< .001$

As previously found by t-tests, there were no significant differences between means in categories 2, 4, 5, and 6, for the entire group.

TABLE VIII

Two-Factor Analysis of Variance with Repeated Measures on Factor "B"
With Three Groups on Basis of Grade IX Ability Percentile Rating

Bloom's Category	Group No.	Number in Group	Test Mean	Retest Mean	Source of Variation	Sum of Squares	Degrees of Freedom	Mean Square	F	Probability
	1	59	5.20	4.86	Within Subjects	221.000	170			
1.1	2	56	5.91	5.79	"B" Main Effects	5.638	1	5.638	4.387	0.0378
					"A x B" Interaction	0.764	2	0.382	0.297	0.7432
					Within Groups					
	1	59	3.02	2.88	Within Subjects	176.500	170			
1.2	2	56	3.82	3.29	"B" Main Effects	6.582	1	6.582	6.578	0.0112
	3	55	4.07	3.91	"A x B" Interaction	2.819	2	1.409	1.409	0.2473
					"B" x Subjects	167.098	167	1.001		
					Within Groups					
	1	59	2.31	2.02	Within Subjects	155.000	170			
1.3	2	56	2.54	2.20	"B" Main Effects	12.981	1	12.981	15.378	0.0001
	3	55	3.25	2.71	"A x B" Interaction	1.050	2	0.525	0.622	0.5382
					"B" x Subjects	140.969	167	0.844		
					Within Groups					
	1	59	3.75	3.36	Within Subjects	227.000	170			
2	2	56	3.96	4.12	"B" Main Effects	1.594	1	1.594	1.204	0.2741
	3	55	4.58	4.40	"A x B" Interaction	4.374	2	2.187	1.652	0.1947
					"B" x Subjects	221.035	167	1.324		
					Within Groups					
	1	59	2.92	2.75	Within Subjects	269.500	170			
3	2	56	3.57	3.30	"B" Main Effects	7.208	1	7.208	4.608	0.0328
	3	55	4.02	3.58	"A x B" Interaction	1.025	2	0.513	0.328	0.7209
					"B" x Subjects	261.266	167	1.564		
					Within Groups					
	1	59	1.75	1.64	Within Subjects	191.500	170			
4	2	56	1.79	1.87	"B" Main Effects	0.235	1	0.235	0.206	0.6503
	3	55	2.35	2.20	"A x B" Interaction	0.882	2	0.441	0.387	0.6796
					"B" x Subjects	190.383	167	1.140		
					Within Groups					
	1	59	1.12	0.93	Within Subjects	79.000	170			
5	2	56	1.07	1.11	"B" Main Effects	0.269	1	0.269	0.576	0.4489
	3	55	1.53	1.51	"A x B" Interaction	0.761	2	0.380	0.815	0.4446
					"B" x Subjects	77.970	167	0.467		
					Within Groups					
	1	59	0.71	0.76	Within Subjects	58.500	170			
6	2	56	0.82	0.80	"B" Main Effects	0.161	1	0.161	0.467	0.4954
	3	55	1.36	1.20	"A x B" Interaction	0.679	2	0.340	0.983	0.3761
					"B" x Subjects	57.660	167	0.345		
					Within Groups					
	1	59	20.76	19.20	Within Subjects	1762.000	170			
Entire	2	56	23.48	22.48	"B" Main Effects	192.961	1	192.961	20.714	0.0000
Test	3	55	27.40	25.44	"A x B" Interaction	13.352	2	6.676	0.717	0.4898
					"B" x Subjects	1555.687	167	9.315		
					Within Groups					

However, this analysis showed no evidence of interaction between ability group and retention. No significant differences in retention between different groups appeared in any of the categories or on the test as a whole.

Answer to Problem 2 (a) (iii)

The question of Problem 2 (a) (iii) was as follows: Are there any significant differences between different student groups in the retention of subject matter of Science 20 Physics in the various categories of Bloom's Taxonomy when the groups are formed on the basis of Grade IX ability percentile ratings?

The answer is that the analysis of variance with three such groups has shown no significant differences between them in their retention in any of the categories of Bloom's Taxonomy or on the test as a whole.

Some explanation is sought for the fact that there appeared no demonstrable relationship between performance on the Grade IX Ability Test and retention in Science 20 Physics. The nature of the ability test itself may be part of the answer. It is composed of two sections, one to test verbal, the other quantitative, ability. It would therefore not be likely to give a valid indication of ability in science, or more specifically, in physics. Since for these reasons the ability test could not be expected to be a good predictor of attainment in physics, still less could it be expected to predict retention in this subject.

It must be concluded that other factors such as specific ability and interest in the subject play a much larger part in retention in Science 20 Physics than ability as represented by the Grade IX ability percentile rating.

ANALYSIS OF VARIANCE WITH TWO GROUPS

Groups on Basis of Sex

A final analysis of variance was done with the subjects divided into two groups on the basis of sex, to determine whether any significant differences were apparent between boys and girls in their retention of knowledge in the different categories. There were 78 boys and 92 girls. Results of this analysis of variance are shown in Table IX.

Findings of Analysis of Variance with Two Groups on the Basis of Sex

With regard to the main effect, i.e., retention by the entire group, there was complete agreement with t-tests and other analyses of variance previously considered.

With regard to interaction between group and retention, this attained significance in only one category, 1.2. It was also significant on the test as a whole.

TABLE IX

Two-Factor Analysis of Variance with Repeated Measures on Factor "B"
With Two Groups on Basis of Sex

1 - Male
2 - Female

Bloom's Category	Group No.	Number in Group	Test Mean	Retest Mean	Source of Variation	Sum of Squares	Degrees of Freedom	Mean Square	F	Probability
	1	78	5.69	5.84	Within Subjects	221.00	170			
1.1	2	92	5.84	5.49	"B" Main Effects	5.314	1	5.314	4.154	0.0431
					"A x B" Interaction	0.792	1	0.792	0.619	0.4323
					"B" x Subjects Within Groups	214.895	168	1.279		
	1	78	3.76	3.76	Within Subjects	176.500	170			
1.2	2	92	3.51	3.00	"B" Main Effects	5.508	1	5.508	5.592	0.0192
					"A x B" Interaction	5.508	1	5.508	5.592	0.0192
					"B" x Subjects Within Groups	165.484	168	0.985		
	1	78	2.73	2.46	Within Subjects	155.000	170			
1.3	2	92	2.65	2.16	"B" Main Effects	12.137	1	12.137	14.376	0.0002
					"A x B" Interaction	1.020	1	1.020	1.208	0.2732
					"B" x Subjects Within Groups	141.842	168	0.844		
	1	78	4.12	4.15	Within Subjects	227.000	170			
2	2	92	4.07	3.77	"B" Main Effects	1.372	1	1.372	1.032	0.3111
					"A x B" Interaction	2.325	1	2.325	1.749	0.1877
					"B" x Subjects Within Groups	223.305	168	1.329		
	1	78	3.42	3.35	Within Subjects	269.500	170			
3	2	92	3.54	3.08	"B" Main Effects	6.253	1	6.253	4.040	0.0460
					"A x B" Interaction	3.217	1	3.217	2.078	0.1512
					"B" x Subjects Within Groups	260.030	168	1.548		
=	1	78	1.83	1.96	Within Subjects	191.500	170			
4	2	92	2.05	1.85	"B" Main Effects	0.129	1	0.129	0.115	0.7350
					"A x B" Interaction	2.365	1	2.365	2.103	0.1489
					"B" x Subjects Within Groups	189.006	168	1.125		
	1	78	1.42	1.33	Within Subjects	79.000	170			
5	2	92	1.08	1.04	"B" Main Effects	0.316	1	0.316	0.675	0.4124
					"A x B" Interaction	0.069	1	0.069	0.147	0.7016
					"B" x Subjects Within Groups	78.615	168	0.468		
	1	78	1.15	1.04	Within Subjects	58.500	170			
6	2	92	0.79	0.82	"B" Main Effects	0.185	1	0.185	0.537	0.4647
					"A x B" Interaction	0.397	1	0.397	1.151	0.2848
					"B" x Subjects Within Groups	57.918	168	0.345		
	1	78	24.13	23.59	Within Subjects	1762.000	170			
Entire Test	2	92	23.53	21.21	"B" Main Effects	173.134	1	173.134	19.119	0.0000
					"A x B" Interaction	67.502	1	67.502	7.454	0.0070
					"B" x Subjects Within Groups	1521.375	168	9.056		

Answer to Problem 2 (b)

The question asked in Problem 2 (b) was: Are there any significant differences between different student groups in their retention of subject-matter of Science 20 Physics in the various categories of Bloom's Taxonomy when the groups are formed as follows: two groups on the basis of sex?

The answer is that boys surpassed girls in category 1.2, ways and means of dealing with specifics, and on the test as a whole. Levels of confidence were beyond 2% and 1% respectively.

Although it reached significance in only one category, there was a trend, as shown by cell means, for boys to retain a larger proportion than girls in all but categories 5 and 6. The cumulative effect of this trend is shown in results for the test as a whole.

The explanation of the superior retention of boys most probably lies in their generally greater interest in the subject and in more contact with its practical applications.

CHAPTER V

SUMMARY OF FINDINGS, CONCLUSIONS, AND IMPLICATIONS

Summary of Findings for the Total Group of Students

The investigation revealed significant differences between test and retest means for the entire group of students in the following categories of Bloom's Taxonomy: 1.1, 1.2, 1.3, 3, and on the test as a whole. No significant differences were apparent in categories 2, 4, 5, and 6.

Findings With Student Sample Divided Into Groups

Three Groups on Basis of June Test

With three nearly equal groups on the basis of June test scores, significant differences in retention between groups occurred in categories 1.2, 1.3, and 3, and on the test as a whole.

Three Groups on Basis of September Retest

With three nearly equal groups on the basis of September retest scores, significant differences appeared between groups in category 2 and on the test as a whole.

Three Groups on Basis of Grade IX Ability Percentile

When three groups were formed on the basis of Grade IX ability percentile ratings, no significant differences between groups appeared anywhere in the analysis.

Two Groups on Basis of Sex

When the sample was divided into two groups, one of boys, the other of girls, significantly superior retention was shown by the boys in category 1.2, and on the test as a whole.

CONCLUSIONS

Conclusions Drawn on Basis of Entire Group Performance

The investigation has shown that, on the average, there was definitely more forgetting in some categories than in others. Forgetting was significant in knowledge of specifics, of ways and means of dealing with specifics, and of universals and abstractions in a field. It was also significant in application of knowledge.

In ability to comprehend, analyze, synthesize and evaluate, there was, on the average, no loss. In fact, in many cases there was evidence of some slight gain in these categories.

In general it can be said that retention in the categories of higher, more structured learnings, is better than in the lower, simpler, less related types.

Conclusions by Comparison of Performance of Sub-Groups

Differences between groups of students in their retention of knowledge in the different categories appeared to depend largely on the basis of formation of the groups.

There is no evidence from this study that the proportion of material retained in Science 20 Physics is directly related to ability as measured by the Grade IX Ability Test.

Boys show better retention in Science 20 Physics than do girls. This may be due to the generally greater interest of boys in the subject.

IMPLICATIONS

Implications for Educators

This study has given strong indications that learned material is better retained if it is part of a structured pattern. It therefore behooves educators to attempt to promote the formation of structural patterns in which learnings can fit and be retained in a meaningful context.

It is advisable for an educator to be familiar with a method of classifying learnings, such as Bloom's Taxonomy, so that teaching can be directed toward developing the higher cognitive skills and abilities as well as those lower in the hierarchy.

Drill on facts without understanding of their derivation and context is likely to show disappointing returns in view of the amount of effort expended.

The generally low achievement on higher skills shown by the students tested in this study strongly indicates that more effort of teachers needs to be directed toward the development of these skills.

If students are brought to comprehend subject-matter so that they can apply, analyze, synthesize, and evaluate, then both their performance and retention are likely to be highly satisfactory.

Implications for Students

A student must get at the meaning of the subject-matter. He must not merely memorize formulas, but should know what they mean, where they come from, how to derive them.

The ability to recall facts rapidly diminishes, but the ability to comprehend, analyze, synthesize and evaluate in terms of knowledge once gained appears to suffer very little or no diminution with time. These higher learnings, then, should be vigorously striven for. They can be promoted by practice in thinking beyond the immediate problem, by analyzing and interpreting new situations, by reconstructing learned material into new patterns, by developing and applying criteria to proposed methods of dealing with problems.

Implications for Research

Since the early 1930's very few studies of retention of learning have been carried out. Yet the topic of retention must be important, for the ultimate value of learning depends upon how much is retained.

More studies of retention are needed to answer such questions as "what to teach" and "how to teach it." Much of the value of such studies may well be in bringing about reappraisal of teaching goals and methods.

The study here reported may serve to suggest some techniques which can be employed, such as the use of Bloom's Taxonomy in classifying test items, and the processing of results by t-tests and analyses of variance. It may also have demonstrated some techniques to be avoided or improved upon. For example, a larger number of items should be provided in the higher categories, especially items of less difficulty. However, to provide easier items in these categories appears to be a very formidable task. To make a thorough investigation of retention in the upper categories of Bloom's Taxonomy, it may be necessary to teach deliberately for mastery of these higher cognitive skills and abilities.

The topic of retention of learning is a challenging one which invites further research.

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APPENDIX A

TEST with KEY and INSTRUCTIONS

APPENDIX A

Important Information

The 50-item test as finally processed is shown with items numbered 1 to 50. The number which each item carried in the original 65-item test is shown in brackets.

Deleted items are shown after the 50-item test with their original numbers unchanged.

The number at the right-hand margin after each item indicates its classification according to Bloom's Taxonomy.

SCIENCE 20 -- PHYSICS

Instructions to Students

In the test which follows pick the best choice to complete each statement and circle its letter on the answer sheet which is supplied.

You must be careful, as many of the choices are not entirely wrong, but in each case there is one which is better than any of the others.

Example: I. The prefix which means one-tenth is

(a) milli (b) centi (c) deci (d) kilo

Since the correct choice is (c), this letter is circled opposite No. I as shown.

I. a b ⓒ d

Answer all questions to the best of your ability.

(2x52)
2 marks each

(16) 1. To calculate the amount of work done when a body is moved, we multiply the distance it is moved by the

(a) mass of the body
(b) weight of the body
(c) force used in moving the body
(d) frictional force encountered by the body 1.2

(1) 2. "The quantity of matter in an object" defines its

(a) weight
(b) mass
(c) density
(d) volume 1.1

(35) 3. The image in a pinhole camera will decrease in size if you increase

(a) the distance of the image from the pinhole
(b) the distance of the object from the pinhole
(c) the size of the object
(d) the size of the pinhole 2

4. The color of light whose velocity in glass is greatest
(10) is

(a) blue
(b) green
(c) red
(d) violet 1.1

5. A virtual image is formed in a plane mirror because
(53)

(a) the reflected rays of light belonging to the same point on an object converge behind the mirror
(b) the reflected rays of light belonging to the same point on the object are not convergent
(c) the incident rays of light from the same point on an object are all divergent
(d) the reflected rays of light from the same point on an object are all divergent 4

6. The theory of the propagation of light which was first
(6) devised by Max Planck was the

(a) corpuscular theory
(b) emission theory
(c) quantum theory
(d) wave theory 1.1

7. Halving the distance from a light source to a surface
(23) will

(a) cut the candlepower in half
(b) double the number of lumens
(c) double the illumination on the surface
(d) increase the illumination fourfold 1.3

8. One of the following bodies which is not luminous is
(5)

(a) electric light
(b) incandescent vapor
(c) moon
(d) sun 1.1

(3) 9. Two objects are placed in water. One sinks and one floats. For this to happen it is necessary that there be a difference in

(a) weights of the objects
(b) densities of the objects
(c) volumes of the objects
(d) buoyant forces on the objects 2

(40) 10. A hoist will raise a ton of ore 110 feet in one minute. The horsepower rating of the hoist would be

(a) 1.3
(b) 6.7
(c) 11.1
(d) 55.2 3

(29) 11. The index of refraction of a body depends on

(a) its shape
(b) its thickness
(c) both of these factors
(d) neither of these factors 1.3

(14) 12. When we multiply pressure by the area upon which the pressure acts, our answer will be in units of

(a) force
(b) work
(c) potential energy
(d) power 1.2

(11) 13. The number of significant digits in 0.0604 is

(a) 2
(b) 3
(c) 4
(d) 5 1.2

(8) 14. The dark lines in the sun's spectrum are due to

(a) absence of certain incandescent elements
(b) presence of certain cooler gaseous elements
(c) dispersion of spectral colors
(d) Fraunhofer diffraction 1.1

15. (17) In finding the specific gravity of a substance, an expression which <u>will not</u> give the correct result is:

(a) S.G. = $\frac{\text{density of substance}}{\text{density of water}}$

(b) S.G. = $\frac{\text{Mass of unit volume of substance}}{\text{Mass of unit volume of water}}$

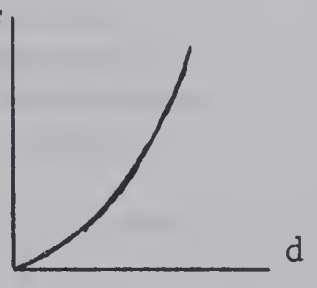
(c) S.G. = $\frac{\text{Mass of any volume of substance}}{\text{Mass of equal volume of water}}$

(d) S.G. = $\frac{\text{weight of substance in air}}{\text{weight of substance in water}}$ 1.2

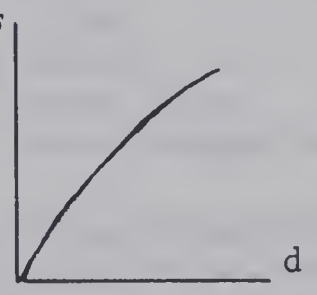
16. (48) Newton's Law of Gravitation is expressed algebraically:

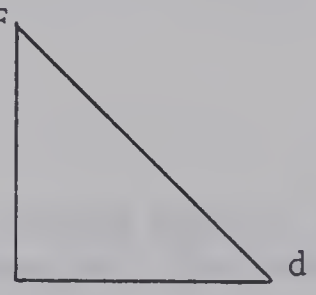
$$F = \frac{Mm}{d^2}$$

Assuming that M and m remain constant, the one graph from among the following which shows how the force changes as the distance between the masses varies is

(a)


(c)


(b)


(d)


17. (2) The first experimental study of magnetism was made by

(a) Aristotle
(b) Bacon
(c) Galileo
(d) Gilbert 1.1

18. To prevent chromatic aberration in small telescopes, the
(33) common procedure is to use

(a) reversed prisms, one of flint glass and one of crown glass, in the eyepiece
(b) a concave lens of flint glass with a convex lens of crown glass in the objective
(c) prismatic reflectors instead of mirrors 2
(d) a parabolic mirror instead of a lens for the objective

19. An object is floating in water. If we add a small quantity
(58) of alcohol (specific gravity .79) to the water, with which it is completely miscible, we will observe that

(a) the object will neither rise nor settle in the liquid
(b) the object will rise higher in the liquid
(c) the object will sink lower in the liquid
(d) the object's reaction depends on its density 5

20. If you were to measure the thickness of a wire with great
(12) exactness, the instrument to use would be a

(a) caliper
(b) micrometer
(c) spherometer
(d) pyrometer 1.2

21. A parallel beam of light is best diffused by
(18)

(a) a prism
(b) a mirror
(c) frosted glass
(d) a dark colored object 1.3

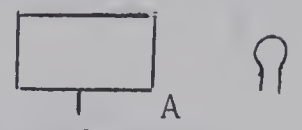
22. The particular angle of incidence at which the ray when
(9) refracted makes an angle of 90 degrees with the normal is called the

(a) angle of deviation
(b) critical angle
(c) refracting angle
(d) angle of total reflection 1.1

23. (63) You suspect that a certain soluble compound contains hydrogen. Which of the following would be the most reliable way of checking your suspicion?

(a) Place a sample of the compound in a bunsen flame and determine if any water vapor is produced.
(b) Heat the compound to incandescence and analyze the light produced with a pyrometer.
(c) Vaporize some of the material in a flame and use a spectroscope to analyze the light produced
(d) Electrolyze a solution of the compound using Hoffman's apparatus 6

24. (43)



Screen A is placed 2 feet from a light source, and screen B is placed 12 feet from the same light source. The illumination at A is "x" times that at B. The value of "x" is

(a) 6
(b) 24
(c) 36
(d) 72 3

25. (64) One particular type of mirage which a traveller in the desert often sees is that of an apparent layer of water over the sand in the distance. The most reasonable explanation for this phenomenon, keeping in mind that it appears to be on the ground at a considerable distance from the observer is:

(a) the "appearance" of water is caused by heat waves in the air
(b) total reflection of rays from the sky occurs from the boundary of a warmer air layer against the sand
(c) a very distant body of water is made visible because of refraction in the overhead atmosphere
(d) a very distant body of water is made visible by reflection from an overhead layer of atmosphere 6

26. (37) In white light an oil film on water shows various colors. These colors are produced by

(a) polarization
(b) dispersion
(c) interference
(d) diffusion

2

27. (45) A lens with a focal length of 50cm. has a power which is 2 dioptres less than that of another lens. The focal length of the other lens is

(a) 200 cm.
(b) 100 cm.
(c) 25 cm.
(d) 12½ cm.

3

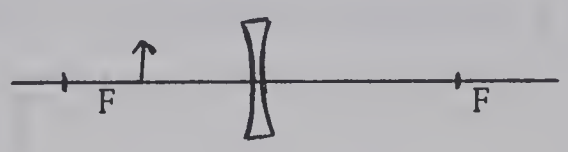
28. (42) A hydrometer weighing 12 gm. displaces 15 c.c. of a liquid in which it is floating. If now it is placed in water

(a) it will float higher than before
(b) it will float lower than before
(c) it will float at the same level as before
(d) its reaction is not predictable

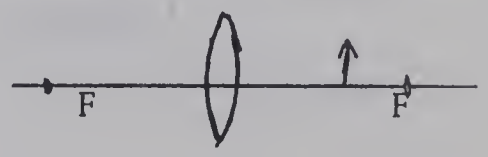
3

29. (54) Which of these arrangements will produce a virtual image larger than the object?

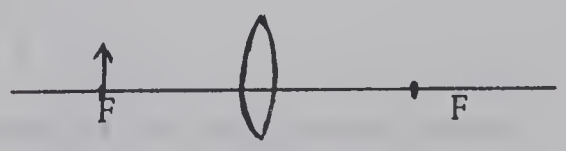
(a)



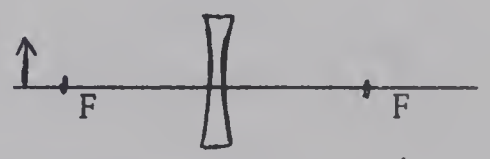
(b)



(c)



(d)



4

30. (39) If oil costs 50¢ per quart, a liter of oil should cost

(a) 28¢
(b) 44¢
(c) 57¢
(d) 88¢

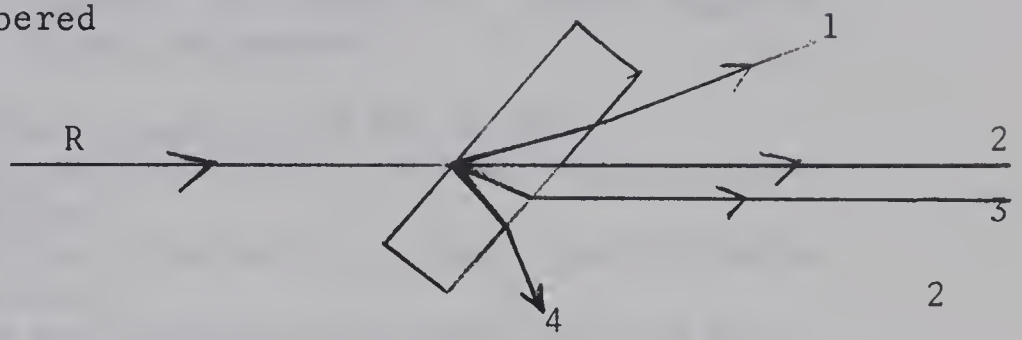
3

31. A measure of the amount of attraction the earth has for
(4) an object is expressed by the object's

(a) mass
(b) weight
(c) density
(d) specific gravity 1.1

32. The ray, R, will follow
(36) the path numbered

(a) 1
(b) 2
(c) 3
(d) 4



2

33. Archimedes' Principle states that an object when immersed
(21) in a fluid

(a) has an apparent weight equal to weight of fluid displaced
(b) displaces an amount of fluid equal to its own weight
(c) loses in apparent weight an amount equal to weight of fluid displaced
(d) is buoyed up by a force equal to its own weight 1.3

34. Which of the arrangements shown in Problem 29 above will
(55) produce the smallest image of a given object?

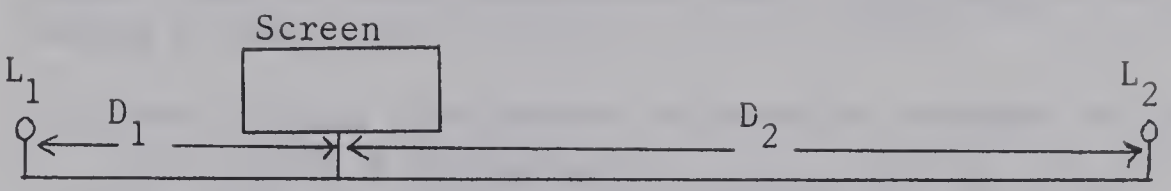
(a) a
(b) b
(c) c
(d) d 4

35. A penumbra is <u>not</u> formed when
(52)

(a) the object is smaller than the light source
(b) the light source is smaller than the object
(c) the light comes from a point source
(d) the object is close to the light source 2

36.

(38)



L_1 is a lamp of 1 candlepower, and L_2 is a lamp of 4 candlepower. In solving for the distance, d_1, of the screen from L_1 when the photometer is balanced, we get two different answers, one positive and one negative. The negative answer represents

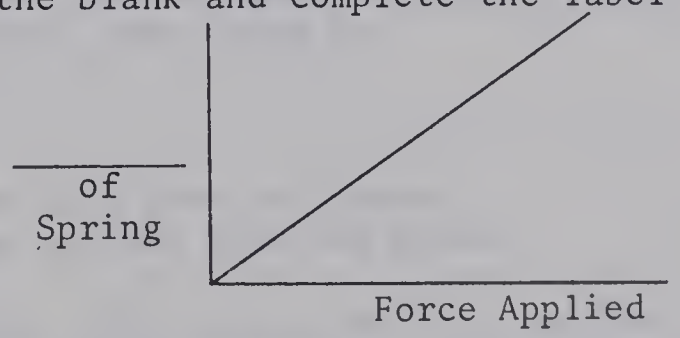
(a) an imaginary position of the screen
(b) imaginary position of L_1 so that the photometer will balance
(c) a second position for L_2 so that the photometer will balance
(d) a second position for the screen so that the photometer will balance 2

37. (13) The least equipment needed to find the density of an irregularly shaped solid body (denser than water) is

(a) some water and a graduated cylinder
(b) some water, a beaker, and some string
(c) water, beaker, string, and a balance
(d) water, beaker, string, balance, overflow can and catch bucket 1.2

38. (32) So that this graph correctly illustrates Hooke's Law, the right word to fill the blank and complete the label on the vertical axis is

(a) length
(b) resistance
(c) strength
(d) stretch



2

39. (31) At a temperature of $4^{o}C$ the density of water is a maximum. This is another way of saying that at this temperature

(a) its volume is greatest
(b) its mass is greatest
(c) its mass is least
(d) its volume is least

(3) 40. One of the following expressions which does not correctly define a "mean solar day" is

(a) the average time between successive passages of the sun across a meridian
(b) one three-hundred-and-sixty-fifth part of a year
(c) 86,400 seconds
(d) the time which the earth takes to make one complete rotation on its axis 3

(19) 41. The expression which does not refer to the same quantity as the others is

(a) candlepower
(b) foot-candles
(c) $\frac{I}{d^2}$
(d) $\frac{\text{lumens}}{\text{sq. ft.}}$ 1.2

(20) 42. Your text says that "Physics is specially concerned with the means of measurement." The fundamental measurements which physics is concerned with making are

(a) mass, speed, and direction
(b) mass, time, and position
(c) mass, time, and length
(d) mass, distance, and force 1.3

(26) 43. It is shown by experiment that whenever a mirror or lens produces a magnified image, that image is

(a) real
(b) virtual
(c) closer to mirror or lens than the object
(d) farther from mirror or lens than the object 1.3

(46) 44. The yellow light of sodium vapor in an electric arc has a wavelength of about 5900 Angstrom units. This means that the length of the wave is about

(a) 5.9×10^{-5} cm.
(b) 59 thousandths of an inch
(c) 5.9×10^{-9} meters
(d) none of the lengths given 3

45. (57) A specific gravity bottle was weighed when empty, then filled with water and weighed, then filled with alcohol and weighed again. A 2-gram weight used in all three weighings had its markings so obliterated that it was read as "1 gram." The effect of this error was that the value reported for specific gravity of alcohol was

(a) too high
(b) too low
(c) not affected
(d) likely, but not certain, to be in error 5

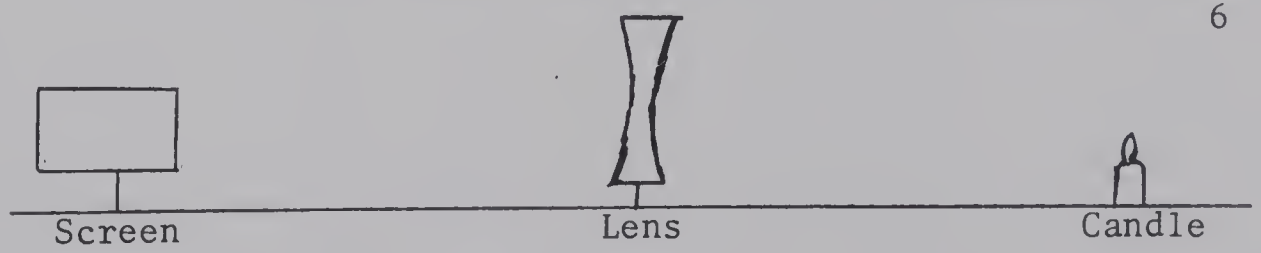
46. (7) The grease spot photometer was invented by

(a) Bunsen
(b) Fresnel
(c) Joly
(d) Rumford 1.1

47. (61) In a magazine article it was stated that if a craft is being rocketed away from the earth fast enough, its speed would offset the pull of gravity, and a man in the craft would feel weightless. This statement should be evaluated as being

(a) true, since two opposite forces are acting simultaneously and one can cancel the other's effect
(b) true, since the weight of an object decreases rapidly as it gets farther from the earth's center
(c) false, since the floor of the man's compartment will be pushing up on him as the rocket rises, thus resulting in a feeling of increased weight
(d) false, since no object in the earth's gravitational field can be weightless, and so cannot seem weightless 6

48. (60)



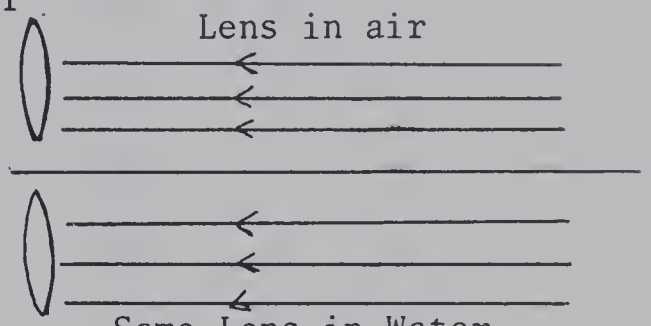
A student who was attempting to find the focal length of a concave lens experimentally, using the apparatus illustrated, appeared uncertain of the correct procedure. The student should be instructed as follows:

(a) Leave the screen in the same position, but move the candle until a clear image is obtained.
(b) Move the screen back and forth until the image is clear upon it.
(c) Put both screen and candle on the same side of the lens and adjust their positions.
(d) With a "finder" instead of a screen, use the method of parallax to locate the image. 5

49. (41) A body weighs 20 pounds in air and 15 pounds in water. Its specific gravity is

(a) 0.75
(b) 1.33
(c) 3.0
(d) 4.0 3

50. (59) Immersion of a convex lens under water



(a) will increase the focal length
(b) will decrease the focal length
(c) causes no change in focal length
(d) will change the rate that light travels through the lens 5

ANSWER SHEET

Science 20 -- Physics

Inter-System Testing, 1966

Student's Name _____

School _____

Division or County _____

Instructions to Students:

After you have very carefully selected the best choice to complete each statement in the Science 20 Physics test, circle its letter opposite its number on the answer sheet below.

1. a b c d	18. a b c d	35. a b c d
2. a b c d	19. a b c d	36. a b c d
3. a b c d	20. a b c d	37. a b c d
4. a b c d	21. a b c d	38. a b c d
5. a b c d	22. a b c d	39. a b c d
6. a b c d	23. a b c d	40. a b c d
7. a b c d	24. a b c d	41. a b c d
8. a b c d	25. a b c d	42. a b c d
9. a b c d	26. a b c d	43. a b c d
10. a b c d	27. a b c d	44. a b c d
11. a b c d	28. a b c d	45. a b c d
12. a b c d	29. a b c d	46. a b c d
13. a b c d	30. a b c d	47. a b c d
14. a b c d	31. a b c d	48. a b c d
15. a b c d	32. a b c d	49. a b c d
16. a b c d	33. a b c d	50. a b c d
17. a b c d	34. a b c d	

KEY --- Physics

Science 20 --- Inter-System Testing 1966

Important: This test in physics constitutes part of a thesis project. It is fully realized that it contains many difficult items; therefore raw scores will not be generally high.

The kind co-operation of teachers is requested in forwarding all students' answer sheets in physics to their superintendent. A sample will be selected for statistical analysis and follow-up. Information pertaining to individual persons and schools will be kept strictly confidential.

Your co-operation is greatly appreciated by the writer of this test.

35. c	18. b	1. c
36. d	19. c	2. b
37. c	20. b	3. b
38. d	21. c	4. c
39. d	22. b	5. a
40. b	23. c	6. c
41. a	24. c	7. d
42. c	25. b	8. c
43. d	26. b	9. b
44. a	27. c	10. b
45. c	28. a	11. d
46. a	29. b	12. a
47. c	30. b	13. b
48. d	31. b	14. b
49. d	32. c	15. d
50. a	33. c	16. c
	34. d	17. d

NOTE TO TEACHERS WHICH PRECEDED RETEST KEY

KEY --- Physics Retest

Science 20 --- Inter-System Testing 1966

Important Information for Teachers

This retest constitutes the final phase of gathering data for a thesis project investigating students' retention of knowledge in different categories classified according to Bloom's Taxonomy of Educational Objectives.

There is no obligation on teachers to score the answer sheets. However, this key is provided for those who wish to do so for the purpose of comparing first and second scores.

The kind co-operation of teachers in forwarding all answer sheets to their superintendents will be greatly appreciated by the struggling thesis writer.

All information pertaining to individual persons and schools will be kept strictly confidential.

When the study is completed, a summary of findings will be sent to all schools which participated.

ITEMS DELETED FROM ORIGINAL TEST

15. If we multiply 2.1 by 2.56 and by 9.547, the proper answer is

(a) 51
(b) 51.4
(c) 51.38
(d) 51.379 1.2

22. To project an image on the wall, the type of mirror to use is

(a) concave
(b) convex
(c) plane
(d) any one of these 1.3

24. Energy is measured in the same units as

(a) force
(b) power
(c) pressure
(d) work 1.3

25. One principle which applies to all mirrors is

(a) angle of incidence = angle of reflection
(b) the focal point is on the principal axis
(c) $\frac{1}{Di} + \frac{1}{Do} = \frac{1}{F}$
(d) $\frac{Hi}{Ho} = \frac{Di}{Do}$ 1.3

27. When the object is placed inside the focal length of a concave mirror, the image is

(a) real and inverted
(b) virtual and erect
(c) at a distance greater than the focal length
(d) closer to the mirror and smaller than the object 1.3

28. A parabolic mirror is used as a reflector in a searchlight because

(a) all light which enters parallel to the principal axis is reflected through the focus
(b) all light rays from the focal point are reflected parallel to the principal axis
(c) a converging pencil of light is formed
(d) the reflecting power of a parabolic mirror is greater than that of any other shape 1.3

34. The focal length of a lens is dependent on

(a) the color of light
(b) the material of the lens
(c) the shape of the lens
(d) all of the above 2

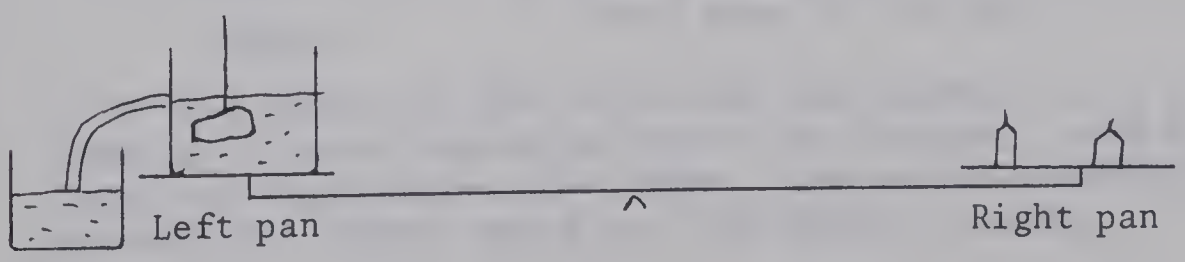
44. If two plane mirrors are inclined at an angle of 72 degrees to each other, the total number of images of an object placed between them is

(a) 2
(b) 3
(c) 4
(d) 5 3

47. A filter or filter combination which could be used to transmit only the green from a beam of white light would be

(a) green
(b) green, blue, and yellow
(c) yellow and blue
(d) violet, green, and red 3

49. An overflow can filled just to the overflow spout is balanced by counterweights on the other scale pan. A heavy lead stopper held by a thread from the teacher's hand is lowered into the can and kept there, but is not allowed to touch the sides or bottom. The observation is that



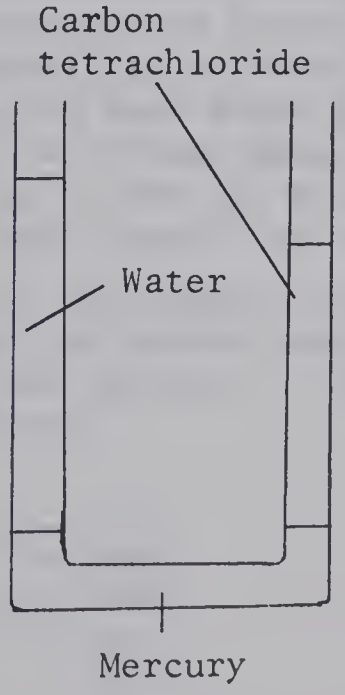
(a) the left pan sinks because lead is much heavier than water
(b) the left pan rises because the load is lightened by the water overflow.
(c) the pans remain balanced because the weight of lead supported equals weight of water lost
(d) the left pan sinks because of a downward force equal and opposite to the buoyant force on the lead. 4

50. The following is a set of readings taken in an experiment with an inclined plane 12 feet long, which rises to a height of 3 feet.

Observation No.	1	2	3	4
Load (grams)	128	200	300	400
Force required (grams)	60	75	102	125

A correct interpretation of the data given is that

(a) the force needed can be calculated from the length and height.
(b) if you include the overcoming of friction, then "work in = work out."
(c) efficiency of the plane increases as load increases.
(d) the inclined plane is a method of saving work. 4

51. 

In using the U-tube shown to determine the specific gravity of carbon tetrachloride, a wrong value was obtained although all calculations were done very carefully. The most likely reason for the error was that

(a) water and carbon tetrachloride columns were not the same length
(b) one arm of the tube was larger in cross-section than the other
(c) the tops of the water and carbon tetrachloride columns were not at the same level
(d) the mercury was not at the same level in both arms of the tube 4

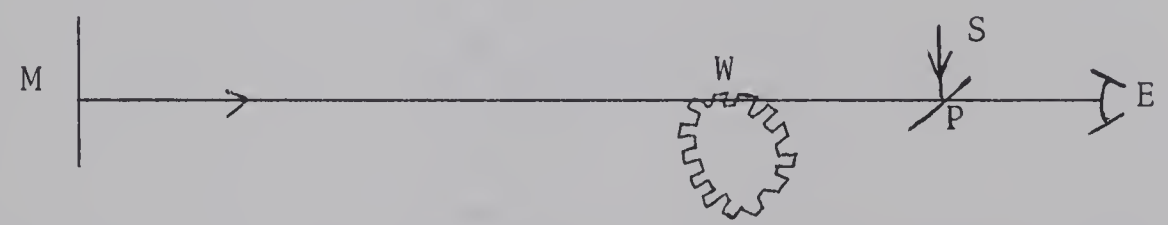
56. In a "Fun House" at the circus you see yourself in a mirror combination which makes you appear as follows: head shrunken, trunk and legs normal, feet huge. The mirror combination to produce this effect would be, from upper to lower:

(a) concave, convex, plane
(b) concave, plane, convex
(c) convex, plane, concave
(d) plane, concave, convex 4

62. A motor was tested and found capable of delivering 20 horsepower. It drove a 2000-lb. car over a supposedly level road at a rate of 44 feet per second. From this the frictional force was calculated and reported to be 250 lb. wt. Later it was found that the road had a very slight down grade in the direction that the car had been moving. The effect of this error would mean that

(a) the horsepower rating was too high
(b) friction was less than reported
(c) friction was more than reported
(d) there could have been an error in measuring either the weight or rate of the car 6

65.



The illustration shows the setup of Fizeau's apparatus for determining the velocity of light. The light reflected by the partly silvered mirror, P, to the distant mirror, M, is reflected back along its own path. When the wheel is at rest, the return beam passes back through the same gap and is visible to the eye at E. When the wheel is rotated at just the right speed, the return way is blocked by the next tooth.

If n is the number of teeth, d the distance in miles to the reflecting mirror, and r the number of revolutions per second, then the velocity of light in miles per second is given by the expression,

(a) $V = ndr$
(b) $V = 2ndr$
(c) $V = 4ndr$
(d) $V = \frac{ndr}{2}$ 5

KEY

Answers to Items Deleted From Original Test

15. a

22. a

24. d

25. a

27. b

28. b

34. d

44. c

47. c

49. c

50. c

51. d

56. c

62. c

65. c

APPENDIX B

ITEM ANALYSIS

APPENDIX B

ITEM ANALYSIS

This analysis is based on results of administering the test shown in Appendix A to 94 students in one school division. (See Page 19)

	First Administation		Second Administration	
Item Number	Difficulty Index	Biserial Correlation	Difficulty Index	Biserial Correlation
1	0.830	0.161	0.851	0.355
2	0.789	0.614	0.755	0.216
3	0.755	0.283	0.798	0.284
4	0.660	0.178	0.606	0.106
5	0.624	0.390	0.277	0.226
6	0.596	0.309	0.681	0.277
7	0.574	0.457	0.585	0.543
8	0.564	0.632	0.617	0.583
9	0.543	0.435	0.660	0.443
10	0.543	0.435	0.660	0.443
11	0.511	0.317	0.383	0.336
12	0.511	0.351	0.500	0.236
13	0.500	0.249	0.479	0.242
14	0.489	0.300	0.532	-0.002
15	0.489	0.275	0.500	0.377
16	0.489	0.428	0.394	0.384
17	0.468	0.248	0.468	0.160

ITEM ANALYSIS

	First Administration		Second Administration	
Item Number	Difficulty Index	Biserial Correlation	Difficulty Index	Biserial Correlation
18	0.457	0.174	0.426	0.291
19	0.446	0.628	0.564	0.476
20	0.436	0.481	0.489	0.299
21	0.436	0.417	0.521	0.435
22	0.426	0.631	0.351	0.302
23	0.407	0.519	0.436	0.272
24	0.404	0.503	0.383	0.661
25	0.396	0.328	0.351	0.423
26	0.394	0.219	0.457	0.252
27	0.394	0.175	0.394	0.038
28	0.394	0.577	0.457	0.327
29	0.387	0.248	0.372	0.033
30	0.372	0.438	0.436	0.243
31	0.362	0.230	0.468	0.526
32	0.351	0.447	0.447	0.542
33	0.351	0.476	0.287	0.415
34	0.312	0.534	0.404	0.308
35	0.309	0.390	0.277	0.226
36	0.258	0.331	0.277	0.048
37	0.255	0.152	0.213	0.238
38	0.255	0.152	0.234	0.327

ITEM ANALYSIS

	First Administration		Second Administration	
Item Number	Difficulty Index	Biserial Correlation	Difficulty Index	Biserial Correlation
39	0.245	0.642	0.245	0.437
40	0.245	0.567	0.266	0.392
41	0.245	0.404	0.255	0.386
42	0.234	0.375	0.266	0.317
43	0.213	0.367	0.191	0.332
44	0.202	0.240	0.298	0.460
45	0.196	0.273	0.266	0.337
46	0.191	0.211	0.223	0.644
47	0.132	0.520	0.106	0.493
48	0.109	0.277	0.117	0.392
49	0.085	0.763	0.117	0.603
50	0.054	0.737	0.106	0.665

Test-retest reliability = 0.809

ITEM ANALYSIS OF ITEMS DELETED FROM ORIGINAL TEST

	First Administration		Second Administration	
Item Number	Difficulty Index	Biserial Correlation	Difficulty Index	Biserial Correlation
15	0.255	0.052	0.330	0.018
22	0.245	-0.137	0.277	0.552
24	0.287	-0.176	0.213	0.203
25	0.394	-0.022	0.436	0.188
27	0.351	0.008	0.426	0.206
28	0.255	0.046	0.223	0.268
34	0.362	0.026	0.340	-0.005
44	0.415	0.133	0.447	0.379
47	0.245	0.199	0.181	0.043
49	0.734	-0.309	0.723	-0.018
50	0.340	0.035	0.426	0.033
51	0.543	-0.178	0.585	-0.013
56	0.387	-0.086	0.340	-0.013
62	0.198	-0.088	0.223	0.079
65	0.200	0.198	0.277	0.562

APPENDIX C

TEST-RETEST SCORES

and

PERCENTILE RATINGS

APPENDIX C

STUDENTS' TEST AND RETEST SCORES AND PERCENTILE RATINGS

Student Number	Test Score	Retest Score	Ability %ile	Student Number	Test Score	Retest Score	Ability %ile
1	9	11	30	22	17	14	7
2	10	15	21	23	17	19	97
3	11	21	64	24	17	16	15
4	11	14	21	25	17	19	56
5	12	12	9	26	17	16	54
6	12	15	41	27	17	18	52
7	13	15	54	28	18	20	47
8	14	14	43	29	18	22	68
9	14	17	64	30	18	21	32
10	14	14	45	31	18	27	75
11	14	16	73	32	19	24	52
12	14	13	24	33	19	28	21
13	15	14	33	34	19	24	64
14	15	13	75	35	19	15	39
15	15	17	60	36	19	21	60
16	15	16	81	37	19	20	14
17	15	11	26	38	19	18	35
18	15	20	32	39	19	19	68
19	16	17	26	40	19	20	64
20	16	23	49	41	20	16	77
21	16	20	52	42	20	17	39

Student Number	Test Score	Retest Score	Ability %ile	Student Number	Test Score	Retest Score	Ability %ile
43	20	15	43	65	22	25	60
44	20	15	43	66	22	21	56
45	20	20	93	67	22	16	79
46	20	22	36	68	22	14	43
47	21	17	60	69	22	27	86
48	21	22	56	70	22	25	39
49	21	18	19	71	22	22	92
50	21	11	49	72	22	19	62
51	21	21	39	73	22	19	37
52	21	16	23	74	22	20	7
53	21	26	35	75	23	18	9
54	21	22	41	76	23	23	87
55	21	28	93	77	23	21	73
56	21	22	75	78	23	17	86
57	21	12	23	79	23	16	56
58	21	18	54	80	23	26	68
59	21	22	79	81	23	21	15
60	21	13	54	82	23	15	39
61	22	23	39	83	23	20	35
62	22	23	72	84	24	16	39
63	22	23	15	85	24	18	21
64	22	18	49	86	24	24	79

Student Number	Test Score	Retest Score	Ability %ile	Student Number	Test Score	Retest Score	Ability %ile
87	24	24	58	109	26	30	73
88	24	23	75	110	26	27	58
89	24	19	24	111	26	26	26
90	24	25	47	112	26	23	45
91	24	28	92	113	26	21	77
92	24	18	58	114	26	24	70
93	24	28	35	115	27	22	60
94	24	12	26	116	27	23	24
95	24	24	81	117	27	21	96
96	24	20	75	118	27	23	70
97	24	17	6	119	27	29	72
98	24	23	47	120	27	28	64
99	24	24	90	121	27	21	58
100	25	25	47	122	27	25	75
101	25	17	56	123	27	22	79
102	25	22	90	124	27	23	66
103	25	20	73	125	28	18	86
104	25	20	79	126	28	21	81
105	25	25	33	127	28	24	45
106	25	26	60	128	28	22	66
107	25	27	87	129	28	23	47
108	25	24	58	130	28	18	24

Student Number	Test Score	Retest Score	Ability %ile	Student Number	Test Score	Retest Score	Ability %ile
131	28	24	58	153	32	37	90
132	29	25	47	154	32	26	54
133	29	23	81	155	32	33	84
134	29	24	93	156	32	30	87
135	29	30	79	157	32	29	77
136	29	22	26	158	33	24	84
137	29	29	87	159	33	37	49
138	29	28	77	160	33	33	95
139	29	30	45	161	33	33	93
140	30	23	70	162	34	29	82
141	30	25	56	163	34	31	95
142	30	35	58	164	35	34	75
143	30	27	92	165	35	31	94
144	30	25	87	166	36	29	70
145	31	34	62	167	37	40	87
146	31	25	99	168	38	36	82
147	31	28	68	169	39	33	89
148	31	31	89	170	40	30	62
149	31	28	81				
150	32	30	56				
151	32	37	87				
152	32	23	81				